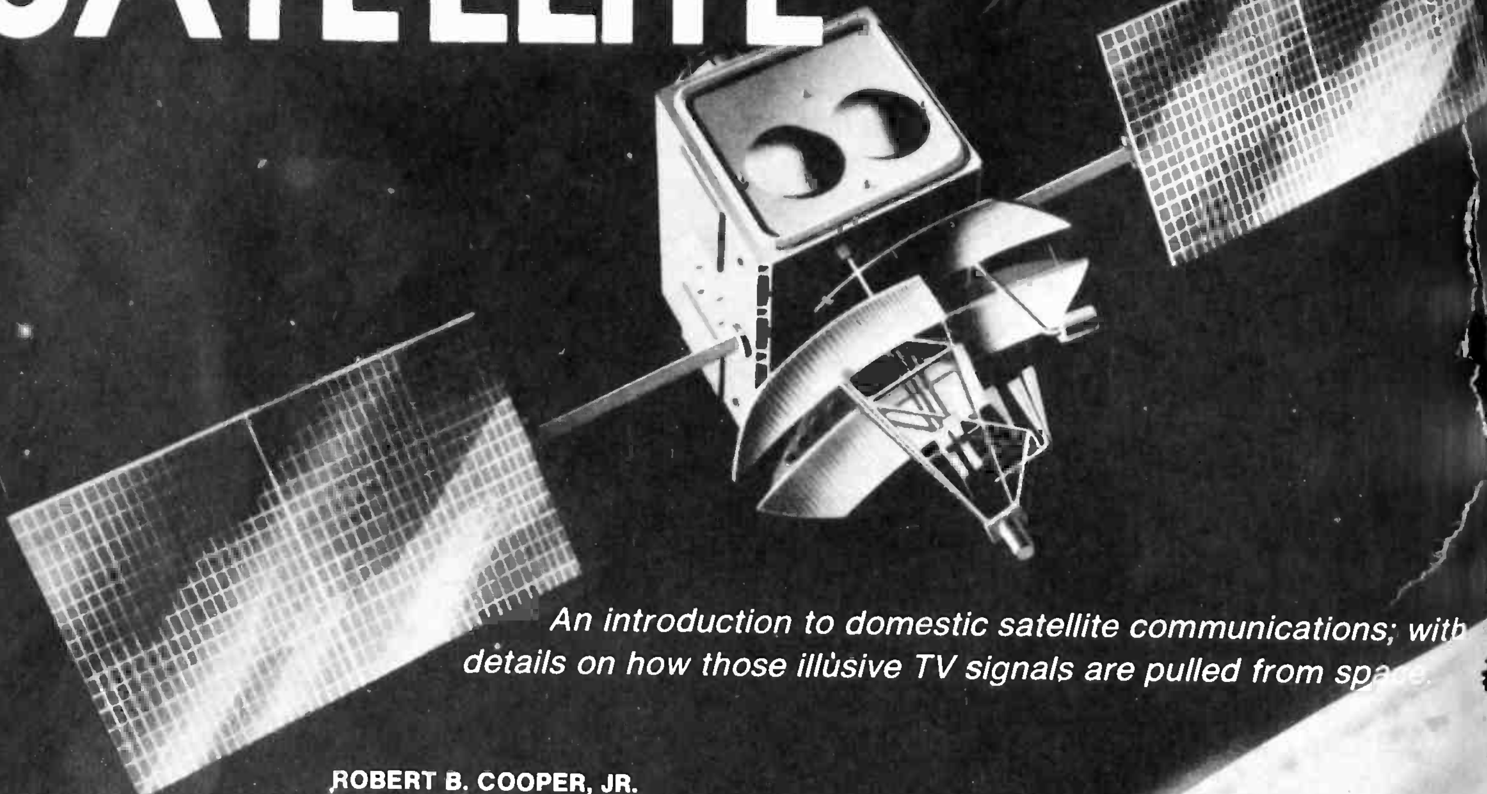
Radio-Electronics®

SPECIAL REPRINT
BUILD A BACKYARD SATELLITE TV RECEIVER

Home Reception *via* SATELLITE



An introduction to domestic satellite communications; with details on how those illusive TV signals are pulled from space.

ROBERT B. COOPER, JR.

YOU MAY BE TOO YOUNG TO HAVE BEEN A PART OF THE EXCITING 1946–1952 "dawn of television era." I was a youngster in upstate New York who spent his high school years souping up 630-type chassis, building cascade and cascode signal boosters with 6BQ7's and trying out every antenna I could lay my design hands on—from stacked 10-element Yagi arrays to 12 wave-length rhombic antennas.

Television happened for me at an infectious age. A paper route helped me maintain a library of that era's **Radio-Electronics** and a host of other valuable trade magazines that were documenting the fast changing world of television technology. Summer odd jobs and caddying at the golf course enabled me to buy aluminum tubing, wire, electronics parts and bargain-basement-priced 630 chassis. In later years I would sometimes wish that I had been born "only five or ten years sooner" so that I would have been old enough by 1950 to have really been in a position to participate fully in the television revolution. "But alas" I would say to myself "that's it for the television revolution. Now that it's established nothing will come along to change it 'that much' so I'll just have to find my nitch someplace else."

And so it was until 1975 when I discovered a whole new television revolution just getting underway—satellite TV transmission and reception. And I have been tracking it, playing an active part in it and enjoying it ever since.

Forget everything you know

If you are in the television business to make a living, you probably think you know all there is to know (or need to know) about reception techniques and equipment. You've tracked down ghosts and explained away weather-caused co-channel interference. You've doped out MATV systems and traced bad components. You've been stuck with an inventory full of "brand name" parts that overnight went off the market, and you own every Sams *Photofact* that they ever printed. Forget it all!

First, let me tell you a bit about the TV reception in my present home, some 20 miles outside of Oklahoma City. We have the usual three major networks as well as PBS (*P*ublic *B*roadcasting *S*ystem). And like a good majority of the United States, that is all we have (or *had* until the fall of 1977).

In August 1977 I placed some 1 × 2 stakes in our sidelawn and backhoed enough clay to let me refill the holes with a few pieces of properly formed steel and around 4 yards of concrete. Then, in September 1977, I brought in a crew of friends and this funny-looking, 3000-lb., all-steel saucer-shaped apparatus, and in about eight hours we had the saucer mounted on a set of steel posts. (See Fig. 1.) The saucer pointed more or less south of us and up into the sky.

The same evening I sat down with a special receiver and watched the evening news live from Vancouver, British Columbia; a baseball game from Atlanta, GA; and a movie via some-

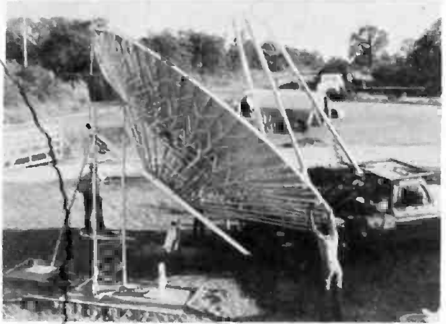


FIG. 1—SATELLITE RECEIVING ANTENNA as it is being installed on steel mounting posts.

thing called HBO (*H*ome *B*ox *O*ffice).

My home is located just 18 airline miles from our local network and PBS stations, and I had always been able to receive the best-looking TV pictures this side of a network monitor, up until that fabled September 1977 evening. Until you have had a high-quality color monitor plugged directly into the video output of a satellite TV receiver and observed 54-dB signal-to-noise-ratio video produced by people who really care about how good it looks when it leaves their studio, you simply have not seen how good NTSC color reception can really be!

Let me digress a bit and explain what satellite television is all about, how it works and why it works the way it does.

How it began

The first man-made satellite was Russia's SPUTNIK (1) in the fall of 1957. It shook a lot of people up as you may recall. The idea of a ton or so of steel and electronics going around and around the world and crossing our country beeping in Morse code and doing who knows what else spurred the U.S. into the space race. We responded by launching a U.S. Airforce satellite named SCORE in December 1958, and to one-up the Russians, we added a prerecorded message from the President of the United States who welcomed in the American space age and the Christmas season.

TABLE 1—INTELSAT GEOSTATIONARY satellites operating in the 3.7- to 4. link frequency band are clustered in three separate areas.

Longitude (west)	Name	Year Launched	Service S
1°	I-IV-F7	1973	Secondary
4°	I-IV-F2	1971	Reserve
19.5°	I-IVA-F4	1977	Reserve
24.5°	I-IVA-F1	1975	Primary
29.5°	I-IVA-F2	1976	Reserve
34.5°	I-IV-F3	1971	Secondary
. . .			
181°	I-IV-F4	1972	Reserve
186°	I-IV-F8	1974	Primary
. . .			
297°	I-IVA-F3	1978	Primary
298.6°	I-IV-F1	1975	Primary
300°	I-IV-F5	1972	Reserve
300°	I-IV-F6	1978	Reserve

SPUTNIK, SCORE and all the satellites that followed them through 1963 had one common fault. They were launched into a "low orbit' and (with reference to a point on earth) they were always moving. To receive messages from or transmit messages to these "low orbit birds" required that the stations working with the satellite know rather precisely its orbit path and the timing of that path, and then be prepared to track the satellite as it came over one horizon, moved in an arc through the sky and finally disappeared beyond the opposite horizon.

In 1963 space technology and rocket power progressed, and SYNCOM, designed and built by the Hughes Aircraft Corporation, was launched—the world's first geostationary (or geosynchronous) satellite. (A geostationary satellite has an orbit directly above the equator and an orbital velocity that matches the rotational velocity of the earth. (See Fig. 2.) In this way, the satellite appears to remain stationary in the sky with respect to a point on the earth.) SYNCOM was an experiment. It provided the capacity to relay either a *single* TV channel or *50* separate telephone conversations; from its orbit above the Equator between Africa and South America, it interconnected North America and Europe with their first real-time (live) television transmissions. By 1965 the geostationary satellite looked like a winner, and 19 countries joined to form something called Intelsat, a consortium of nations that would fund the launching of a series of satellites.

The Intelsat world

With nearly 14 years to grow, the Intelsat system is relatively mature. Today, more than 100 nations belong to the system, which consists of 12 separate satellites located in three distinct "groups." Commercial Intelsat installations cost in the megabuck region, but amateur builders of backyard terminals have successfully tapped into the Intelsat circuit, using surplus-salvaged parabolic antennas as small as 8 feet in diameter and with investments well under $500, as we'll discuss in some detail.

As mature as Intelsat is today, it is in a constant state of evolution. The present satellite series is generally of the so-called Number IV (or "4") class, indicating there have been three previous series. Table 1 lists where they are located; a sharp eye will spot the three "clusters" in operation: One is over the Equator in the Pacific Ocean; another over the Indian Ocean north of the Seychelles Islands; and a third between the tip of Africa and the tip of South America. Each location has as a minimum a "primary" and a "reserve" satellite, but heavy Atlantic and Indian Ocean traffic has resulted in additional satellites in these areas. In 1971 the Intelsat consortium agreed that identical-frequency satellites should be spaced over the equator in 4- to 5-degree increments. In this fashion the large parabolic ground-receiving antennas could intercept the desired satellite's signals without interference from adjacent-position satellites, even though both would be operating on the same frequency simultaneously. The present series IV satellites will begin to be replaced with a new, advanced family of satellites during 1979, the Intelsat V series. We'll look at these later on.

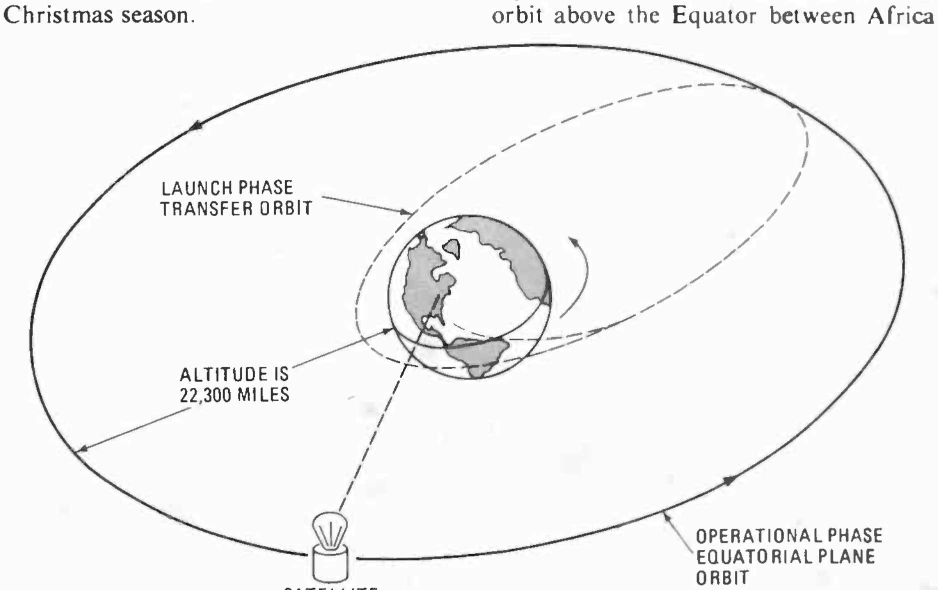
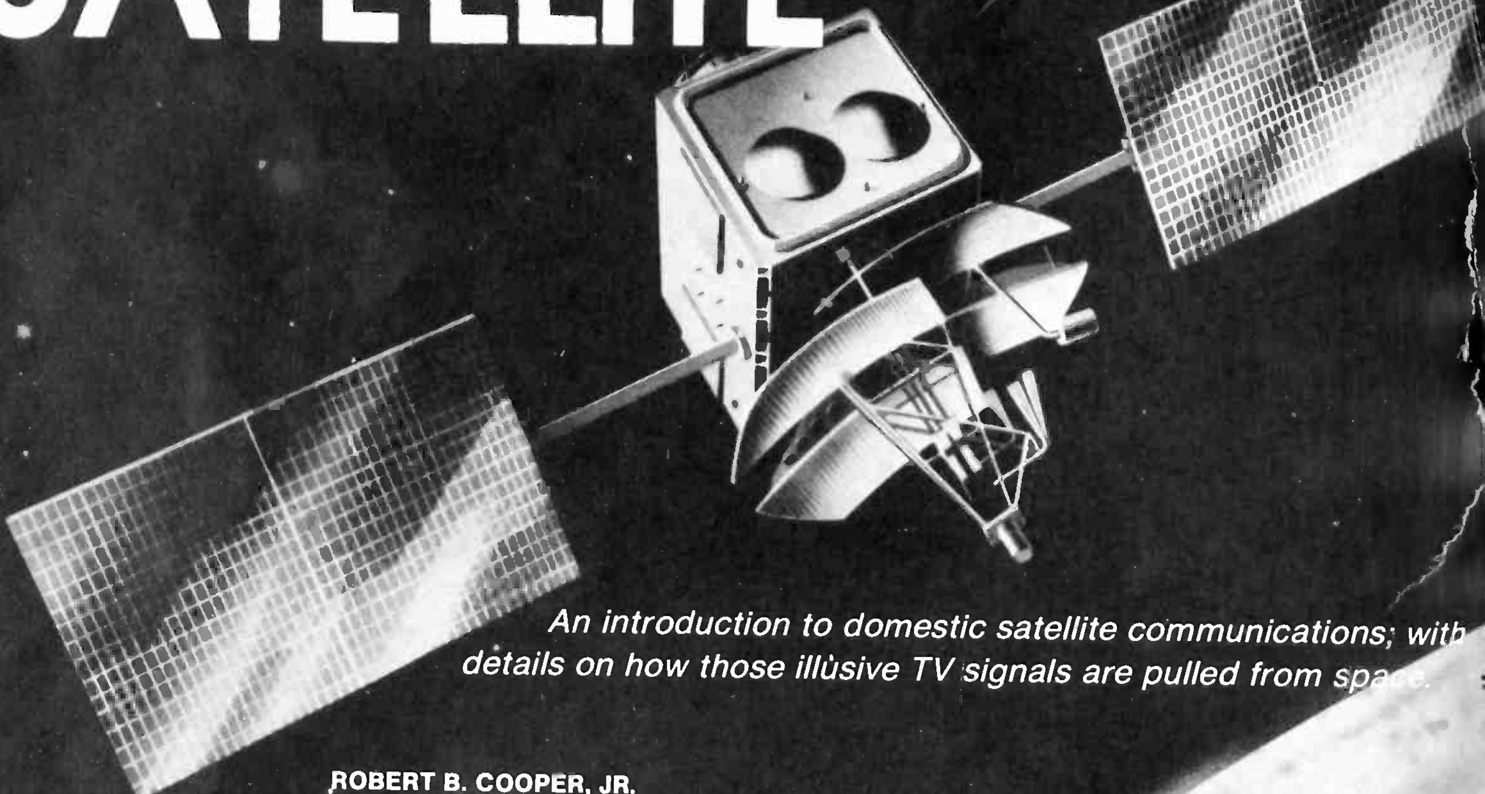


FIG. 2—GEOSYNCHRONOUS ORBIT is achieved by launching satellite into a highly elliptical orbit that is followed by a transfer to an equatorial plane orbit. Satellite's position over equator is typically maintained to ±0.1 degree.

Home Reception *via* SATELLITE



An introduction to domestic satellite communications; with details on how those illusive TV signals are pulled from space.

ROBERT B. COOPER, JR.

YOU MAY BE TOO YOUNG TO HAVE BEEN A PART OF THE EXCITING 1946–1952 "dawn of television era." I was a youngster in upstate New York who spent his high school years souping up 630-type chassis, building cascade and cascode signal boosters with 6BQ7's and trying out every antenna I could lay my design hands on—from stacked 10-element Yagi arrays to 12 wavelength rhombic antennas.

Television happened for me at an infectious age. A paper route helped me maintain a library of that era's **Radio-Electronics** and a host of other valuable trade magazines that were documenting the fast changing world of television technology. Summer odd jobs and caddying at the golf course enabled me to buy aluminum tubing, wire, electronics parts and bargain-basement-priced 630 chassis. In later years I would sometimes wish that I had been born "only five or ten years sooner" so that I would have been old enough by 1950 to have really been in a position to participate fully in the television revolution. "But alas" I would say to myself "that's it for the television revolution. Now that it's established nothing will come along to change it 'that much' so I'll just have to find my nitch someplace else."

And so it was until 1975 when I discovered a whole new television revolution just getting underway—satellite TV transmission and reception. And I have been tracking it, playing an active part in it and enjoying it ever since.

Forget everything you know

If you are in the television business to make a living, you probably think you know all there is to know (or need to know) about reception techniques and equipment. You've tracked down ghosts and explained away weather-caused co-channel interference. You've doped out MATV systems and traced bad components. You've been stuck with an inventory full of "brand name" parts that overnight went off the market, and you own every Sams *Photofact* that they ever printed. Forget it all!

First, let me tell you a bit about the TV reception in my present home, some 20 miles outside of Oklahoma City. We have the usual three major networks as well as PBS (*P*ublic *B*roadcasting *S*ystem). And like a good majority of the United States, that is all we have (or *had* until the fall of 1977).

In August 1977 I placed some 1 × 2 stakes in our sidelawn and backhoed enough clay to let me refill the holes with a few pieces of properly formed steel and around 4 yards of concrete. Then, in September 1977, I brought in a crew of friends and this funny-looking, 3000-lb., all-steel saucer-shaped apparatus, and in about eight hours we had the saucer mounted on a set of steel posts. (See Fig. 1.) The saucer pointed more or less south of us and up into the sky.

The same evening I sat down with a special receiver and watched the evening news live from Vancouver, British Columbia; a baseball game from Atlanta, GA; and a movie via some-

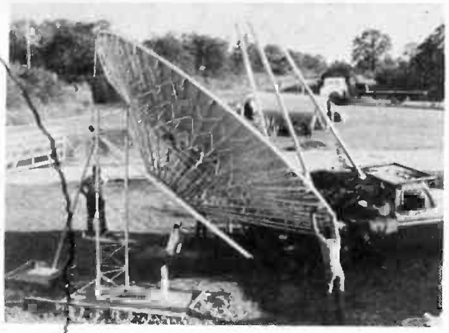


FIG. 1—SATELLITE RECEIVING ANTENNA as it is being installed on steel mounting posts.

thing called HBO (*H*ome *B*ox *O*ffice).

My home is located just 18 airline miles from our local network and PBS stations, and I had always been able to receive the best-looking TV pictures this side of a network monitor, up until that fabled September 1977 evening. Until you have had a high-quality color monitor plugged directly into the video output of a satellite TV receiver and observed 54-dB signal-to-noise-ratio video produced by people who really care about how good it looks when it leaves their studio, you simply have not seen how good NTSC color reception can really be!

Let me digress a bit and explain what satellite television is all about, how it works and why it works the way it does.

How it began

The first man-made satellite was Russia's SPUTNIK (1) in the fall of 1957. It shook a lot of people up as you may recall. The idea of a ton or so of steel and electronics going around and around the world and crossing our country beeping in Morse code and doing who knows what else spurred the U.S. into the space race. We responded by launching a U.S. Airforce satellite named SCORE in December 1958, and to one-up the Russians, we added a prerecorded message from the President of the United States who welcomed in the American space age and the Christmas season.

TABLE 1—INTELSAT GEOSTATIONARY satellites operating in the 3.7- to 4.2-GHz downlink frequency band are clustered in three separate areas.

Longitude (west)	Name	Year Launched	Service Status
1°	I-IV-F7	1973	Secondary
4°	I-IV-F2	1971	Reserve
19.5°	I-IVA-F4	1977	Reserve
24.5°	I-IVA-F1	1975	Primary
29.5°	I-IVA-F2	1976	Reserve
34.5°	I-IV-F3	1971	Secondary
. . .			
181°	I-IV-F4	1972	Reserve
186°	I-IV-F8	1974	Primary
. . .			
297°	I-IVA-F3	1978	Primary
298.6°	I-IV-F1	1975	Primary
300°	I-IV-F5	1972	Reserve
300°	I-IV-F6	1978	Reserve

SPUTNIK, SCORE and all the satellites that followed them through 1963 had one common fault. They were launched into a "low orbit' and (with reference to a point on earth) they were always moving. To receive messages from or transmit messages to these "low orbit birds" required that the stations working with the satellite know rather precisely its orbit path and the timing of that path, and then be prepared to track the satellite as it came over one horizon, moved in an arc through the sky and finally disappeared beyond the opposite horizon.

In 1963 space technology and rocket power progressed, and SYNCOM, designed and built by the Hughes Aircraft Corporation, was launched—the world's first geostationary (or geosynchronous) satellite. (A geostationary satellite has an orbit directly above the equator and an orbital velocity that matches the rotational velocity of the earth. (See Fig. 2.) In this way, the satellite appears to remain stationary in the sky with respect to a point on the earth.) SYNCOM was an experiment. It provided the capacity to relay either a *single* TV channel or *50* separate telephone conversations; from its orbit above the Equator between Africa and South America, it interconnected North America and Europe with their first real-time (live) television transmissions. By 1965 the geostationary satellite looked like a winner, and 19 countries joined to form something called Intelsat, a consortium of nations that would fund the launching of a series of satellites.

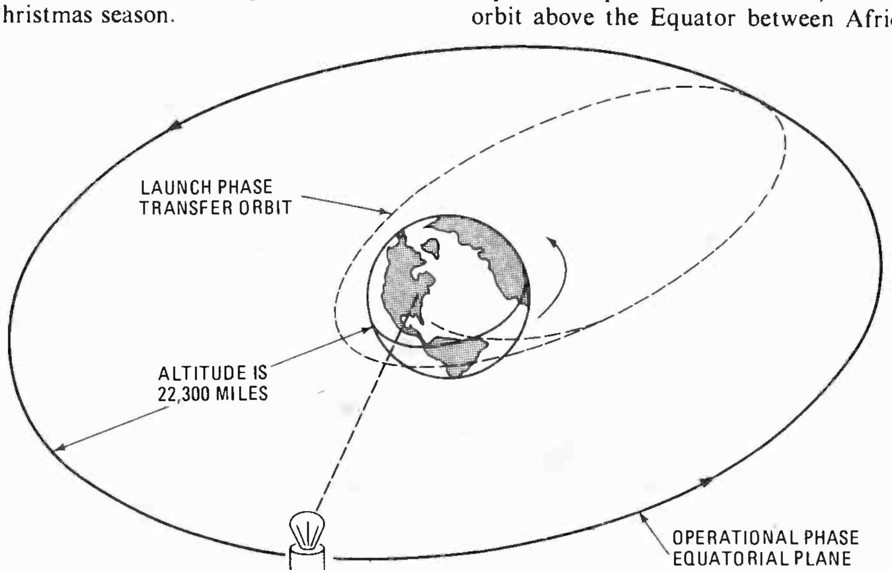


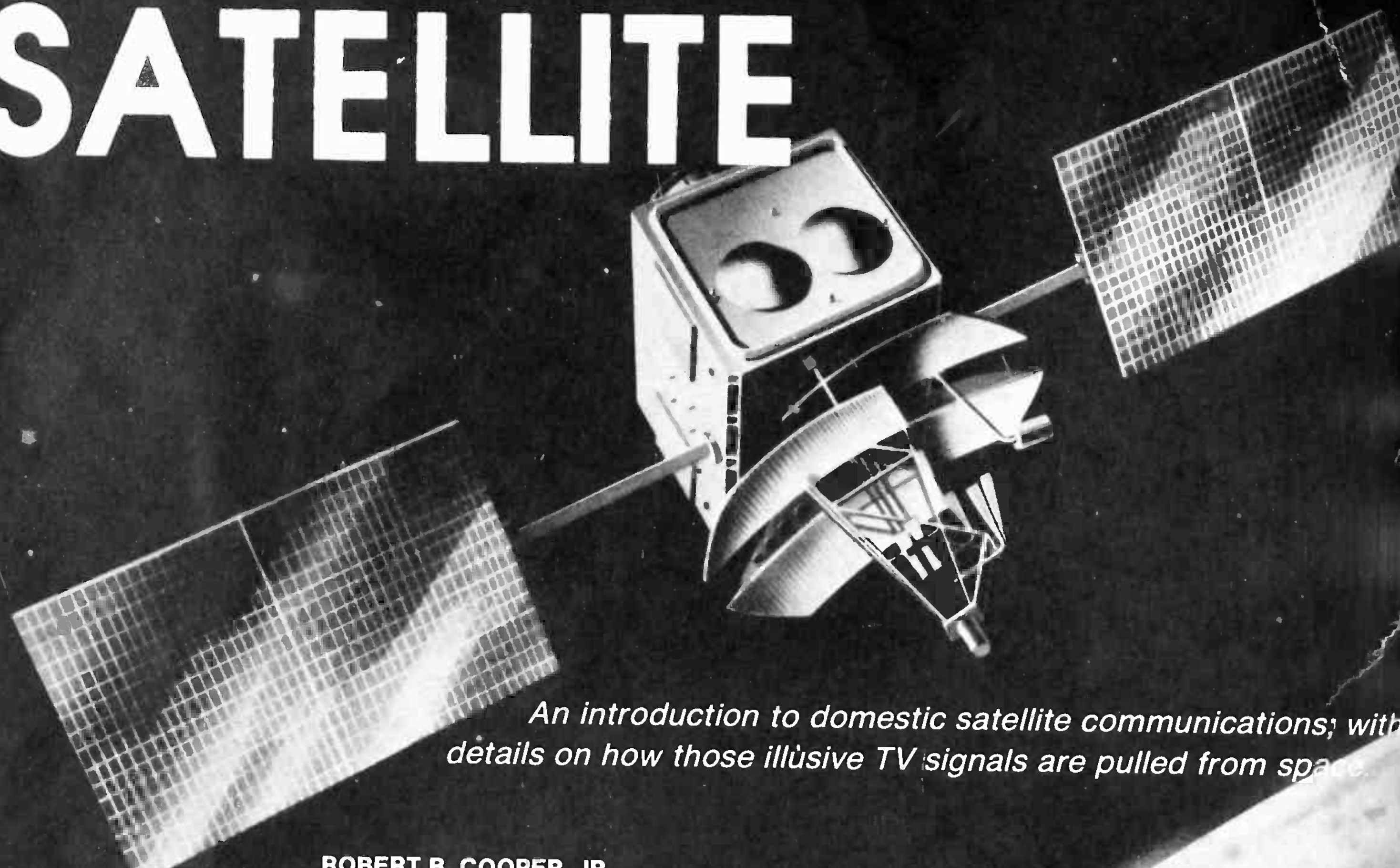
FIG. 2—GEOSYNCHRONOUS ORBIT is achieved by launching satellite into a highly elliptical orbit that is followed by a transfer to an equatorial plane orbit. Satellite's position over equator is typically maintained to ±0.1 degree.

The Intelsat world

With nearly 14 years to grow, the Intelsat system is relatively mature. Today, more than 100 nations belong to the system, which consists of 12 separate satellites located in three distinct "groups." Commercial Intelsat installations cost in the megabuck region, but amateur builders of backyard terminals have successfully tapped into the Intelsat circuit, using surplus-salvaged parabolic antennas as small as 8 feet in diameter and with investments well under $500, as we'll discuss in some detail.

As mature as Intelsat is today, it is in a constant state of evolution. The present satellite series is generally of the so-called Number IV (or "4") class, indicating there have been three previous series. Table 1 lists where they are located; a sharp eye will spot the three "clusters" in operation: One is over the Equator in the Pacific Ocean; another over the Indian Ocean north of the Seychelles Islands; and a third between the tip of Africa and the tip of South America. Each location has as a minimum a "primary" and a "reserve" satellite, but heavy Atlantic and Indian Ocean traffic has resulted in additional satellites in these areas. In 1971 the Intelsat consortium agreed that identical-frequency satellites should be spaced over the equator in 4- to 5-degree increments. In this fashion the large parabolic ground-receiving antennas could intercept the desired satellite's signals without interference from adjacent-position satellites, even though both would be operating on the same frequency simultaneously. The present series IV satellites will begin to be replaced with a new, advanced family of satellites during 1979, the Intelsat V series. We'll look at these later on.

Home Reception *via* SATELLITE



An introduction to domestic satellite communications; with details on how those illusive TV signals are pulled from space.

ROBERT B. COOPER, JR.

YOU MAY BE TOO YOUNG TO HAVE BEEN A PART OF THE EXCITING 1946–1952 "dawn of television era." I was a youngster in upstate New York who spent his high school years souping up 630-type chassis, building cascade and cascode signal boosters with 6BQ7's and trying out every antenna I could lay my design hands on—from stacked 10-element Yagi arrays to 12 wavelength rhombic antennas.

Television happened for me at an infectious age. A paper route helped me maintain a library of that era's **Radio-Electronics** and a host of other valuable trade magazines that were documenting the fast changing world of television technology. Summer odd jobs and caddying at the golf course enabled me to buy aluminum tubing, wire, electronics parts and bargain-basement-priced 630 chassis. In later years I would sometimes wish that I had been born "only five or ten years sooner" so that I would have been old enough by 1950 to have really been in a position to participate fully in the television revolution. "But alas" I would say to myself "that's it for the television revolution. Now that it's established nothing will come along to change it 'that much' so I'll just have to find my nitch someplace else."

And so it was until 1975 when I discovered a whole new television revolution just getting underway—satellite TV transmission and reception. And I have been tracking it, playing an active part in it and enjoying it ever since.

Forget everything you know

If you are in the television business to make a living, you probably think you know all there is to know (or need to know) about reception techniques and equipment. You've tracked down ghosts and explained away weather-caused co-channel interference. You've doped out MATV systems and traced bad components. You've been stuck with an inventory full of "brand name" parts that overnight went off the market, and you own every Sams *Photofact* that they ever printed. Forget it all!

First, let me tell you a bit about the TV reception in my present home, some 20 miles outside of Oklahoma City. We have the usual three major networks as well as PBS (*P*ublic *B*roadcasting *S*ystem). And like a good majority of the United States, that is all we have (or *had* until the fall of 1977).

In August 1977 I placed some 1 × 2 stakes in our sidelawn and backhoed enough clay to let me refill the holes with a few pieces of properly formed steel and around 4 yards of concrete. Then, in September 1977, I brought in a crew of friends and this funny-looking, 3000-lb., all-steel saucer-shaped apparatus, and in about eight hours we had the saucer mounted on a set of steel posts. (See Fig. 1.) The saucer pointed more or less south of us and up into the sky.

The same evening I sat down with a special receiver and watched the evening news live from Vancouver, British Columbia; a baseball game from Atlanta, GA; and a movie via some-

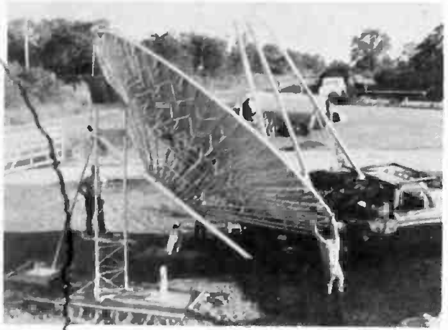


FIG. 1—SATELLITE RECEIVING ANTENNA as it is being installed on steel mounting posts.

thing called HBO (*H*ome *B*ox *O*ffice).

My home is located just 18 airline miles from our local network and PBS stations, and I had always been able to receive the best-looking TV pictures this side of a network monitor, up until that fabled September 1977 evening. Until you have had a high-quality color monitor plugged directly into the video output of a satellite TV receiver and observed 54-dB signal-to-noise-ratio video produced by people who really care about how good it looks when it leaves their studio, you simply have not seen how good NTSC color reception can really be!

Let me digress a bit and explain what satellite television is all about, how it works and why it works the way it does.

How it began

The first man-made satellite was Russia's SPUTNIK (1) in the fall of 1957. It shook a lot of people up as you may recall. The idea of a ton or so of steel and electronics going around and around the world and crossing our country beeping in Morse code and doing who knows what else spurred the U.S. into the space race. We responded by launching a U.S. Airforce satellite named SCORE in December 1958, and to one-up the Russians, we added a prerecorded message from the President of the United States who welcomed in the American space age and the Christmas season.

TABLE 1—INTELSAT GEOSTATIONARY satellites operating in the 3.7- to 4.2-GHz downlink frequency band are clustered in three separate areas.

Longitude (west)	Name	Year Launched	Service Status
1°	I-IV-F7	1973	Secondary
4°	I-IV-F2	1971	Reserve
19.5°	I-IVA-F4	1977	Reserve
24.5°	I-IVA-F1	1975	Primary
29.5°	I-IVA-F2	1976	Reserve
34.5°	I-IV-F3	1971	Secondary
. . .			
181°	I-IV-F4	1972	Reserve
186°	I-IV-F8	1974	Primary
. . .			
297°	I-IVA-F3	1978	Primary
298.6°	I-IV-F1	1975	Primary
300°	I-IV-F5	1972	Reserve
300°	I-IV-F6	1978	Reserve

SPUTNIK, SCORE and all the satellites that followed them through 1963 had one common fault. They were launched into a "low orbit' and (with reference to a point on earth) they were always moving. To receive messages from or transmit messages to these "low orbit birds" required that the stations working with the satellite know rather precisely its orbit path and the timing of that path, and then be prepared to track the satellite as it came over one horizon, moved in an arc through the sky and finally disappeared beyond the opposite horizon.

In 1963 space technology and rocket power progressed, and SYNCOM, designed and built by the Hughes Aircraft Corporation, was launched—the world's first geostationary (or geosynchronous) satellite. (A geostationary satellite has an orbit directly above the equator and an orbital velocity that matches the rotational velocity of the earth. (See Fig. 2.) In this way, the satellite appears to remain stationary in the sky with respect to a point on the earth.) SYNCOM was an experiment. It provided the capacity to relay either a *single* TV channel or *50* separate telephone conversations; from its orbit above the Equator between Africa and South America, it interconnected North America and Europe with their first real-time (live) television transmissions. By 1965 the geostationary satellite looked like a winner, and 19 countries joined to form something called Intelsat, a consortium of nations that would fund the launching of a series of satellites.

The Intelsat world

With nearly 14 years to grow, the Intelsat system is relatively mature. Today, more than 100 nations belong to the system, which consists of 12 separate satellites located in three distinct "groups." Commercial Intelsat installations cost in the megabuck region, but amateur builders of backyard terminals have successfully tapped into the Intelsat circuit, using surplus-salvaged parabolic antennas as small as 8 feet in diameter and with investments well under $500, as we'll discuss in some detail.

As mature as Intelsat is today, it is in a constant state of evolution. The present satellite series is generally of the so-called Number IV (or "4") class, indicating there have been three previous series. Table 1 lists where they are located; a sharp eye will spot the three "clusters" in operation: One is over the Equator in the Pacific Ocean; another over the Indian Ocean north of the Seychelles Islands; and a third between the tip of Africa and the tip of South America. Each location has as a minimum a "primary" and a "reserve" satellite, but heavy Atlantic and Indian Ocean traffic has resulted in additional satellites in these areas. In 1971 the Intelsat consortium agreed that identical-frequency satellites should be spaced over the equator in 4- to 5-degree increments. In this fashion the large parabolic ground-receiving antennas could intercept the desired satellite's signals without interference from adjacent-position satellites, even though both would be operating on the same frequency simultaneously. The present series IV satellites will begin to be replaced with a new, advanced family of satellites during 1979, the Intelsat V series. We'll look at these later on.

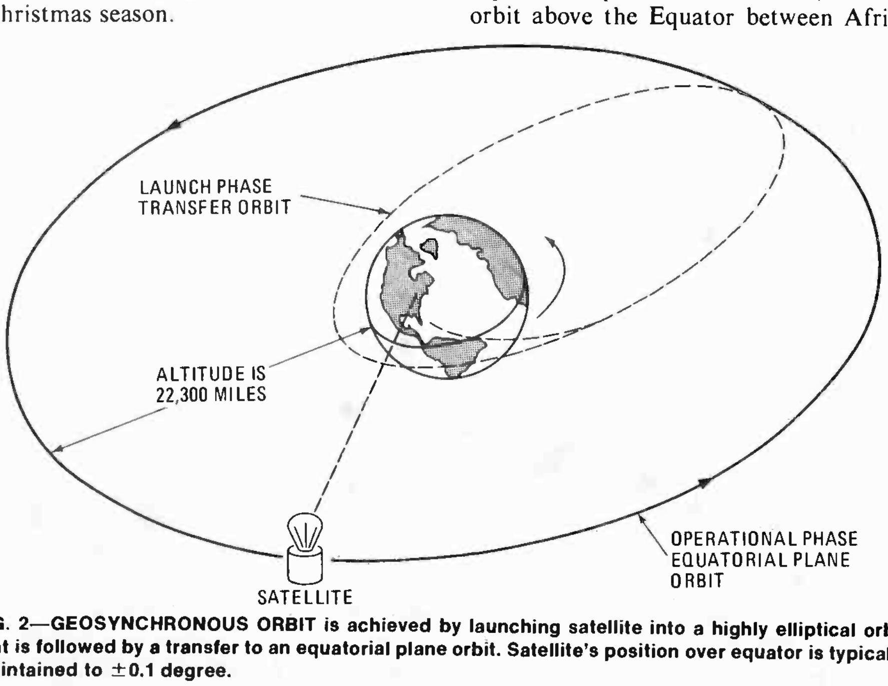


FIG. 2—GEOSYNCHRONOUS ORBIT is achieved by launching satellite into a highly elliptical orbit that is followed by a transfer to an equatorial plane orbit. Satellite's position over equator is typically maintained to ±0.1 degree.

A series of four ½-inch videotapes describing various aspects of satellite television communications are available from *Satellite, Television Technology,* P.O. Box G, Arcadia, OK 73007:

Tape HTS-1, "How The Home Terminal works"

Tape HTS-2, "Private Terminals Today"

Tape HTS-3, "TV Terminal Technical Topics"

Tape HTS-4, "How The Bird Flies"

Tapes are ½-inch and run from 70 to 110 minutes and are in full color. Specify either VHS or Beta format when ordering and enclose payment with order.

Also available is a "Satellite Study Package," including a 52-page booklet explaining private terminals, a 22 by 35 four-color wall chart showing all satellites in operation and how the receive terminal is designed and installed, and a copy of a recent issue of *CATJ* (the worldwide monthly publication dealing with satellite terminal systems) is available.

The first national seminar conference dealing with practical technology for building and operating your own private television receive satellite terminal will be held August 14, 15 and 16 in Oklahoma City.

This conference will feature worldwide experts in the field of private (low cost) satellite terminals demonstrating their equipment design and construction techniques. Numerous operating terminals from 6 to 20 feet in size will be on hand and several firms marketing equipment in this field will be on hand to explain their marketing approaches to home terminal installations. Firms interested in acting as area marketing, servicing and installation affiliates of the national suppliers in this field will have the opportunity to learn about the various products being offered in this field.

Among the systems to be demonstrated will be ten foot terminal systems operating without any LNA devices (utilizing new technology in the receiver area), various approaches to low cost privately built receivers and antenna sub-systems, and a series of sessions on the projected growth and activity in this fast moving area.

Attendance is by advance registration only; for full information contact Satellite, Television Technology, P.O. Box G, Arcadia, OK 73007 (405) 396-2574

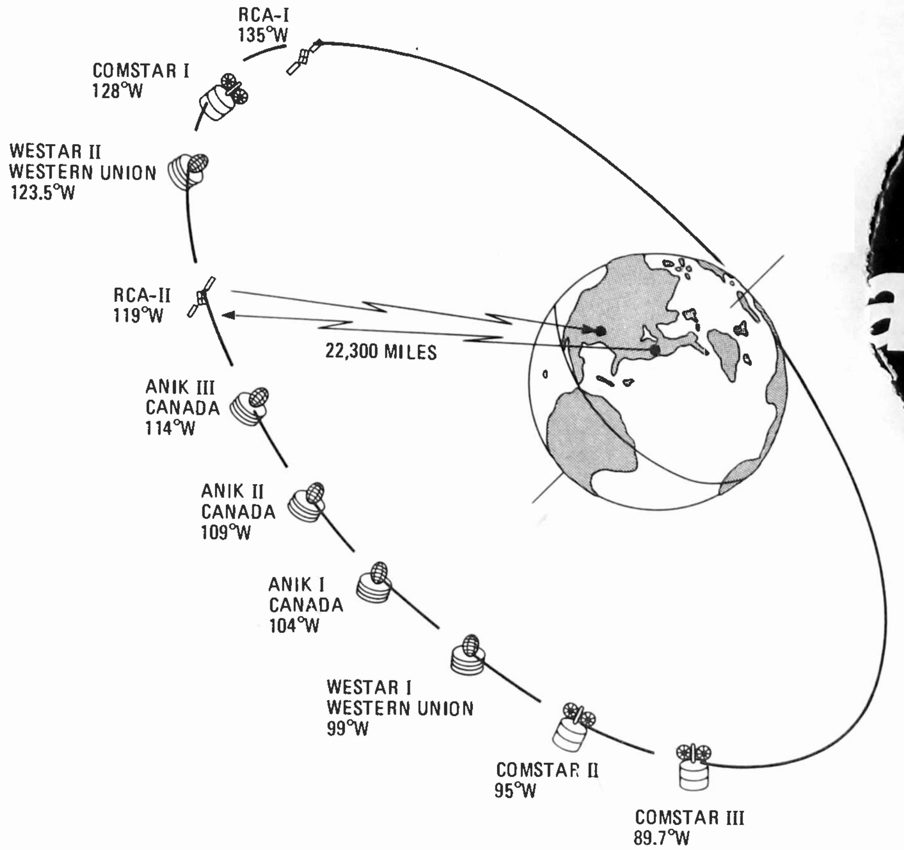


FIG. 3—DOMESTIC SATELLITE "parking" spots. Ten domestic satellites are currently active—3 Canadian and 7 U. S. A. A third WESTAR satellite should have been launched by the time you read this and a third SATCOM is due for launch between October and December of this year.

Domestic satellites

As needed as the Intelsat-type satellites are, they cannot serve all the communications needs of all countries. Some nations, such as the U.S., Canada and Russia, have unique internal needs that in sheer message volume (or circuits required), far outstrip Intelsat's services. For example, in the Atlantic Intelsat cluster five separate satellites have a total flat-out capacity of 100 separate "channels" or transponders. A single transponder can provide (typically) up to 900 voice or message circuits, or one TV channel circuit. Obviously, not all these circuits are used full time, so satellite communications planners take advantage of what are called "peak load times." They attempt to have enough circuits available to handle peak or maximum traffic-time loads. In the long haul, the average number of circuits in use would be somewhat less than 50% of the total capacity available.

Some smaller nations, such as Nigeria, Sudan, Uganda, etc., lease one or more transponder/channels full time from Intelsat to provide ground-to-satellite-to-ground communications for circuits wholly within their own countries (except for the satellite link). Other countries such as Spain, lease full-time circuits to maintain ground-to-satellite-to-ground communications with distant outposts of their nation, for example, television, telephone and data circuits with the Canary Islands.

In 1970–1971 individual countries with projected satellite circuit needs for exceeding Intelsat's capability persuaded other Intelsat nations to allow some portions of the equatorial orbit belt to be reserved for non-Intelsat geostationary satellites, or for domestic satellites. In the interim so-called Domestic Satellite Systems have been activated for Indonesia, Canada, Russia and the U.S. although actually the Russian system was first made operational back in 1965.

In North America the orbit parking region from 70 degrees west longitude (a point due south of New England) to around 135 degrees west (roughly due south of the Alaskan peninsula) is reserved for North American domestic satellites. (See Fig. 3.) Canada was the first to launch a domestic satellite into this region (ANIK I in 1972); and in seven years, 10 other Canadian or U.S. domestic satellites have joined ANIK I. An additional pair of U.S. domestic satellites will join the crowd before 1979 is over. There are 13 satellites in all, and all are parked between 70 degrees west and 135 degrees west.

On a transponder or channel-capacity basis, the North American satellites have the full-load capability to provide as many as 228 separate TV channels, or more than 200,000 telephone voice channels simultaneously—more than twice that available on the Intelsat system. With all that capacity available, you might suspect there is some extremely interesting, perhaps even downright enticing, "television" up there.

Indeed there is. There's a lot of good watching—more than 40 channels worth—to be had from those U.S. And Canadian domestic birds. Next month, we'll take you channel-by-channel, bird-by-bird as we scan programming available to TV viewers in other locations throughout North America. **R-E**

Home Reception *via* SATELLITE

Part 2—The conclusion of a story on domestic satellite communications and its use in distribution of TV programs.

ROBERT B. COOPER, JR.

LAST MONTH WE GOT A LOOK AT EARTH satellites and how they are used in domestic and world-wide communications. Now we'll conclude with a look at the "birds" that carry TV programming of interest.

40-plus TV channels

Imagine you're sitting in your living room on a Sunday afternoon trying to decide what you want to watch. On local TV (or "terrestrial" as we'll call it from this point onward) there are a couple of network-selected regional professional football games, an old movie and a PBS program on how to prepare fall bulbs for planting. The two football games don't include any team you are really interested in, so, let's see what's on the satellites.

We'll start on the eastern edge of the active U.S./Canadian orbit belt with the WESTAR I at 99 degrees west:

Transponder 1 has a pro football game being relayed via satellite to who knows where; Transponders 2, 6 and 10 also feature football games, none of which are on terrestrial TV. Transponders 8, 9 and 11 present three separate PBS programs, one matching the local PBS channel. Transponder 12 is showing a professional soccer game originating in Minneapolis and relayed to Los Angeles. Next, ANIK III, the prime Canadian satellite, is stationed at 114 degrees. On Transponder 4 the CBC is running a "pre-network feed" for a program to be viewed on terrestrial TV later that evening in Canada. Transponder 8 shows a French language movie. Transponder 10 features a Canadian Football League football game, while Transponder 12 is showing a hockey game from Vancouver.

Moving on to RCA SATCOM F2 (at 119 degrees) Transponders 4, 10, 16 and 20 are showing more pro football games. One of these games is being shown on your local NBC affiliate; the other three are not available locally. On Transponder 8, there is an NBC network prefeed of that evening's Walt Disney program, beamed from Los Angeles to New York for network viewing several hours later. Transponder 18 has another prefeed for NBC; this one is a news report for the next day's "Today Show". On Transponder 22 a golf match is being relayed live from a South Carolina locale where it is being transmitted to major-market independent TV stations. Finally, Transponder 23 is carrying a special program presented by the Alaskan Native's Federation, being relayed via satellite to approximately 50 Alaskan "Bush Terminal" sites.

Our next stop is WESTAR II at 123.5 degrees west. Between WESTAR I and SATCOM II we've already run into eight professional football games. Eleven will be played that afternoon so we are not surprised to see engineers, technicians and announcers preparing for one more on transponder 3. Transponder 1 carries New York City's WOR-TV, (a highly rated independent station) which is being fed to cable systems, and is showing an old black-and-white Bogart film. On Transponder 4 Chicago's station WGN is showing *Star Trek* to cable systems. Transponder 7 shows a bullfight, direct from Mexico City's station XEW-TV. Transponder 7 carries an average of 12 hours of Spanish language programming per day, much of which is transmitted directly from Mexico City to a handful of U.S. Spanish language TV stations in Miami, San Antonio and Los Angeles. Way up on Transponder 12 station KTTV in Los Angeles, another independent station being fed to cable systems nationwide, is wrapping up the Dodgers' baseball season. Since this station televises around 100 live Dodger games each year, this broadcast of a Dodger game fits its format.

There's still "nothing to watch," so you head for "the big one," RCA's SATCOM F1 (at 135 degrees west). You run through one of the three ATT/GT&E "telephone company" birds, COMSTAR I, at 128 degrees west. Normally, they don't have much video on them but you check anyway. There on Transponder 14 are a couple of people talking. It seems to be one-half of a conversation. Up on Transponder 18 you find the other half: a group of scientists in Honolulu are talking with politicians in San Juan.

You're not interested, so you now move the antenna round the last notch to SATCOM F1. Surely here you will find something interesting to watch. After all, there are 20 separate almost full time video channels on F1!

On Transponder 1 station KTVU from San Francisco, another independent station, is showing a movie. Transponder 2 carries PTL, a 24-hour-per-day religious-based family entertainment service. Transponder 3 is showing Chicago's WGN broadcast of *Star Trek* again. On Transponder 5 you find "Nickleodeon," a 13-hour-per-day Children's Television Network created by Warner (Brothers) Cable. Transponder 6 carries Atlanta's "Super Station" WTCG, with wrestling. On Transponder 7 "ESP," a New England regional service, is showing playbacks of the area's college football games. Then on Transponder 8 you tune into CBN (*C*hristian *B*roadcasting *N*etwork) the original 24-hour-per-day, satellite-transmitted religious-family channel.

Transponder 9 gives you Knicks basketball game direct from Madison Square Garden (there are more than 1000 hours of Madison Square Garden events on this transponder per year). During the week and in the daytime, Transponder 9 televises U.S. House of Representatives sessions live from Washington, which also totals about 1000 hours per year.

On Transponder 10 you find the West Coast feed for "Showtime," a 12-hour-per-day movie and entertainment service; they are running a current children's (G-rated) hit movie. Tuning to Transponder 11 you find Warner's "Star Channel," a 14-hour-per-day movie and entertainment service, showing a Tom Jones nightclub act from Las Vegas.

Transponder 12 gives you "Showtime's" East Coast channel and a Burt Reynolds movie. One nice thing about having an East and West Coast feed from SHOWTIME (and HBO) is that if you don't have the time to sit down and watch Burt Reynolds now you can come back in three hours and catch it on the West Coast channel at that time. Transponder 13 is running some engineering equipment tests. Transponder 14 also is showing the 24-hour-per-day religious channels—KTBN or Trinity Broadcasting. Only this channel, unlike PTL (Transponder 2) or CBN (Transponder 8), is a regular broadcast TV signal that happens to be sent out via satellite. (CBN and PTTL are special feeds created just for the satellite) On Transponder 16 you find, "Fanfare," a southwestern U.S. regional pay cable service specializing in late-release movies, nightclub and stage acts, and regional sports. Transponder 18 shows some digitally transmitted news from Reuters, on which, with a special receiver adapter, you can watch the latest world news. Transponder 20 is running a movie epic on oil exploration. Transponder 22 has the West Coast feed for HBO (*H*ome *B*ox *O*ffice), and as you tune in they are previewing the day's movie and special fare. Transponder 23 has the HBO family-program service called "Take Two"; and a recently released Walt Disney movie. Finally, in the last transponder position, HBO's East-Coast feed service gives you the movie you wanted to watch. Decisions, decisions: Should you watch the movie now or catch it later on West Coast Transponder 22?

From Canadian hockey live from Vancouver to a bullfight telecast live from Mexico City, you have a choice of 11 professional football games, a motorcycle race from Houston or a soccer match from Minneapolis. These broadcasts are shown with such clarity and resolution that you almost feel compelled to reach out and touch the screen. That's what satellite TV means to those equipped to receive it.

Are people actually watching all these programs? They sure are, and with their own backyard receiving systems.

They all must be millionaires, y[illegible] might think. To be sure, a few had t[illegible] able to afford the prices being charge[illegible] "cable television grade receive term[illegible] back in 1977 or even early 1978. B[illegible] back up a few steps again and take [illegible] at some of the satellite specificatio[illegible]

Microwave in the sky

A satellite is a combination of m[illegible] wave electronics, solar-powered electr[illegible] ics and rocketry. Stripped of all of i[illegible] mind-boggling exotic details, a satellite i[illegible] nothing more than an unattended relay station. It has one set of antennas to receive the transmissions originating on earth (called uplink signals), and another set of antennas to retransmit those signals back to earth (called downlink signals). The uplink signals are between 5.9 GHz and 6.4 GHz (5900 MHz to 6400 MHz), and the downlink signals are between 3.7 GHz and 4.2 GHz (3700 MHz and 4200 MHz).

The uplink and downlink frequencies divided into (typically) 40-MHz-wide channels; and since the up and down frequency bands are 500 MHz wide, there is room for 12.5 such channels both up and down. This results in a maximum capacity of twelve 40-MHz-wide channels, plus some room for ground-to-satellite command signals, satellite-to-ground acknowledgment signals, and a couple of "beacons" to help ground control measure exactly where in space the satellite is located at any given moment. (See Fig. 4.) There can be more than 12 channels on a single satellite, however, and we'll see why that's possible in a later article.

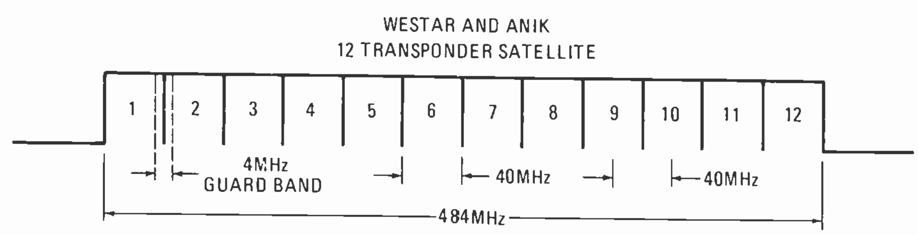


FIG 4—THE DOWNLINK BAND is 500 MHz wide from 3.7 to 4.2 GHz and is divided into 12 channels. Each channel is 40 MHz wide.

The electronics inside most of today's satellites is fairly similar in design up to the output stages and the transmitting antennas. The uplink signals (between 5.9 GHz and 6.4 GHZ) are received via fairly wide-beam "sculptured" antennas that cover all the service area fairly efficiently. Being directional antennas, they have a pattern, and in satellites the center of the antenna pattern is called the "boresight point." The boresight point on the receive antenna is where maximum gain occurs, as well as on the downlink transmitting antenna. All received signals are processed by a broadband (5.9—6.4 GHz) front end. The signals are amplified and fed into a converter stage that translates

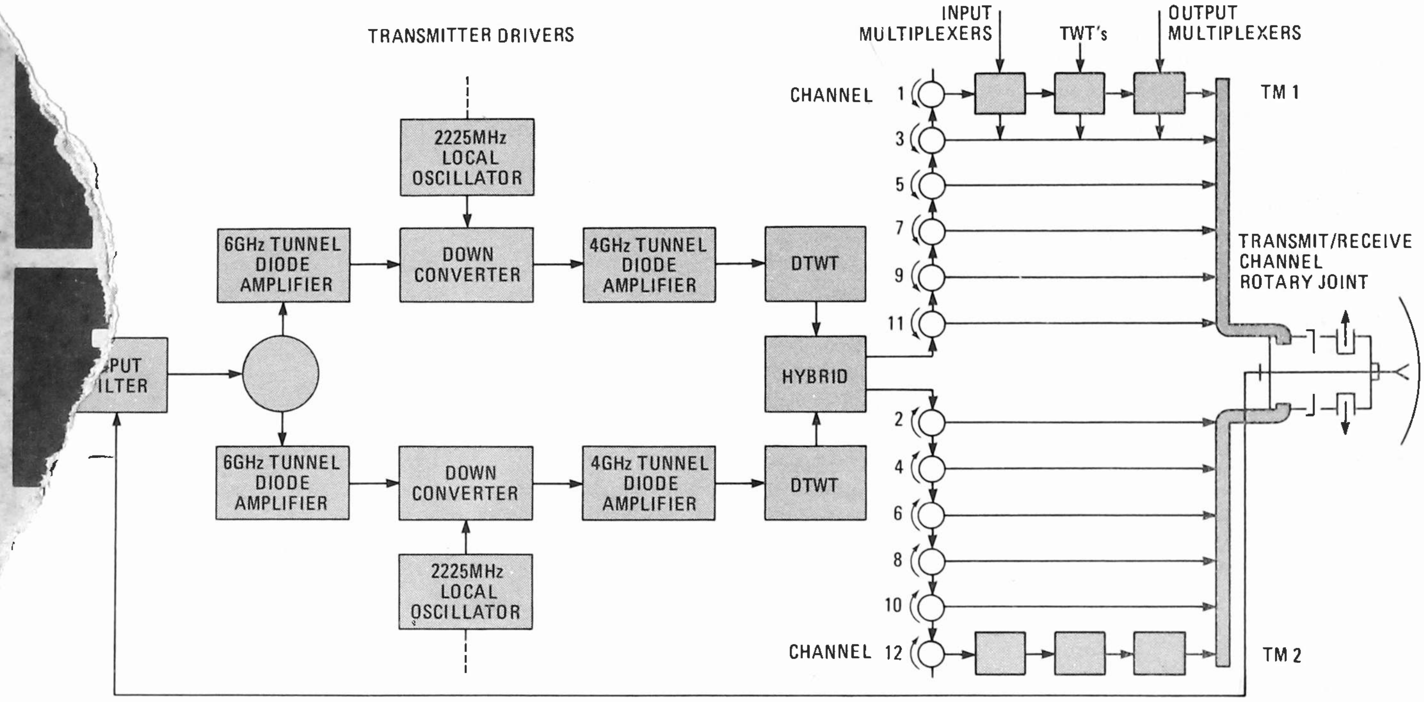


FIG. 5—12 CHANNEL SATELLITE designed by Hughes Aircraft.

their incoming frequency down directly to the appropriate area in the 3.7- to 4.2-GHz range.

Figure 5 is a block diagram of a typical 12-transponder satellite, in this case, the ANIK series. Note that the input side is redundant; this is a security measure in case something in this broadband circuit area should fail prematurely. Once the signals have been translated down to the 4-GHz range, they are fed into the appropriate output-amplifier stages; individual TWT (*T*raveling *W*ave *T*ube) output-amplifier stages are included for each transponder. The peak power at this point is 5 watts (+7 dBw, or decibels above 1 watt) and from there the 5 watts are coupled into the appropriate downlink transmit antennas. The transmit antennas have gain (with reference to a dipole or isotropic source) and the gain added by the directional transmit antenna measured in dB's is added to the power-output level of the TWT amplifier. This results in an effective radiated power (EIRP) for the downlink system. At boresight on the transmit antenna, the power generated is in the +34-dBw to +37-dBw range; this varies slightly from satellite to satellite.

The ground-to-satellite signal path (in the 6-GHz range) requires substantial transmitter power (i.e., 1 kW to 3 kW) plus large antenna gains (50 dB to 60 dB) to saturate the input of the satellite with high-quality (noise-free) signals. Like any relay station, the signal quality returning to earth is only as good as that initially transmitted to the satellite. On the uplink path, free space loss approximates 198 dB.

Our primary interest is in the downlink path since that is where we can particpate. Figure 6 shows how the ANIK satellite views Canada:

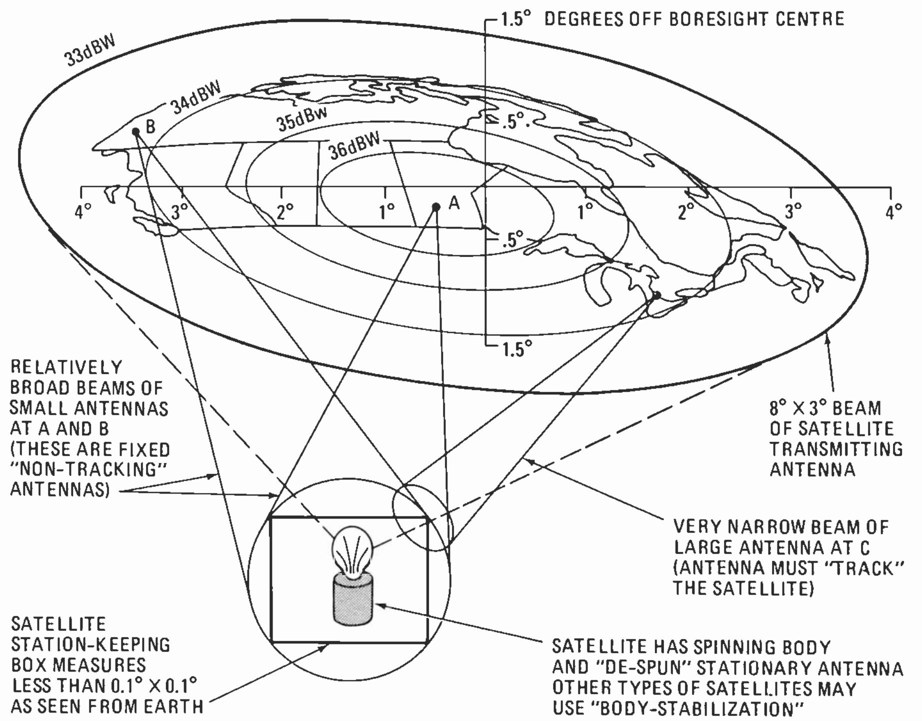


FIG. 6—TYPICAL COVERAGE of the earth's surface by a satellite. Two different approaches to receiving antennas are shown. Small antennas with a broad beam can be non-tracking while large antennas with a narrow beam must track the satellite.

TVRO terminals

TVRO (*Tele**Vision** R*eceive-*O*nly) terminals really came into being when satellite relay service was inaugurated for cable TV companies. Since September 1975 their development has followed closely the established criteria for the big (and expensive) Intelsat stations.

When the first cable TV use of satellites started the present gold rush in the sky, the FCC had no ready system for handling the explosion. Because Intelsat stations were more often than not both reception *and* transmission systems, they naturally required FCC licenses. Domestic terminals that were first installed by RCA, Western Union and (in Canada) by Telesat were both transmit and receive terminals. RCA, for instance, built ground-station terminals near major metropolitan centers and used terrestrial microwaves to link into and out of these centers. The New York City area is served from a location near Sussex, NJ, called Vernon Valley. This site (close to two other major uplink and downlink control sites) is the "first north-south valley location west of New York City where there is terrain shielding" from terrestrial microwave emissions.

This is important because the downlink frequency band in use (3.7 GHz to 4.2

GHz) is a shared band, that is, it is also used as the heavy microwave trunk route for the Bell Telephone Company (and other phone systems) throughout the U.S. Because the telephone company microwave circuits criss cross the country in the same frequency band as the downlink signals from the satellites, there exists a potential for interference. Fortunately, because of the highly directional characteristics of the parabolic antennas used in satellite reception (and the point-to-point "thin-line path" design of terrestrial telephone circuits) the two can operate closely without interference. What interference there is results from transmissions from the terrestrial circuits *to* the satellite-receive terminals since the latter do not transmit. (My own terminal is only 2.4 miles from a major Bell Company relay site, but we have never experienced any interference at our receiving TVRO.)

This does indicate however that occasionally a nearby terrestrial microwave transmitter, located either very close to you and to the side or out in front of you (i.e., on a line towards your satellite heading), could cause some interference with satellite reception. We'll look at solutions to this problem in a later article.

One of the manageable things about the satellite-to-earth system is its high degree of signal-level predictability. Between the excellent station keeping by the "flight engineers" and the well-known parameters of space loss between the satellite and earth, engineers with calculators or enthusiasts with TRS-80 computers can determine within 0.1 dB the type of signal level that can be expected at a given location. Adjusting to 0.1-dB signal-level steps is part of adjusting to satellite technology.

The satellite's signal is contained within a 36-MHz-wide frequency bandwidth. The video signal is frequency-modulated (FM) and the audio signal is also FM, being transmitted as a subcarrier signal at either 6.8 MHz or 6.2 MHz. Because this is an FM/FM system, several important factors must be considered that are not part of normal AM (terrestrial TV) transmission. The foremost factor is called "the FM threshold." Let's simplify what that is:

1. When an FM signal (on an FM set, a two-meter amateur radio, etc.) reaches "full quieting," all background noise is gone.
2. As long as the signal stays above the "threshold of noise," you have no way of judging (without some complicated meter measurement) how close you are to the noise since in "full quieting" there is no noise.
3. The signal may be *far* above quieting (into heavy limiting) or it may be simply right on the ragged edge (on the plus side) of noise; it all sounds the same.
4. However, when you fall out of full quieting (that is, the signal level slips down in level and there is no limiting action) noise appears quite suddenly and often very dramatically.

This indicates that *if* the frequency-modulated satellite video signal could be maintained just above the noise threshold and if the satellite signal was very stable, you could get by with a "low-margin" (for fading) receive system that would to all normal eyeball testing give the same apparent picture quality as a signal that is many many dB stronger than full quieting. When you include in your calculations a parameter called the FM advantage (along with the other parameters of this particular system), a noise-free picture occurs when there is a 48-dB signal-to-noise ratio, as measured at the baseband video signal. FM advantage derived from this type of service, with normal receivers, is around 37 dB (give or take a few tenths of dB's) If you subtract 37 dB (the FM advantage) from the noise free video signal-to-noise ratio (48 dB) this gives you the type of 4-GHz-range carrier-to-noise ratio your receiver must attain: in this case, 48 − 37 = 11 dB. Some fine tuning can be done with these values, but for now they are close enough.

When you go through all the system's mathematical components (satellite EIRP minus free-space loss minus receiver-noise value plus antenna gain) for 48 dB video signal-to-noise pictures, you need a 10-foot parabolic dish antenna with a 2.6-dB noise figure signal preamplifier, also called a low-noise amplifier (LNA). This is if you are within a 36-dBw contour and use a receiver with an adjusted IF bandwidth of 27 MHz.

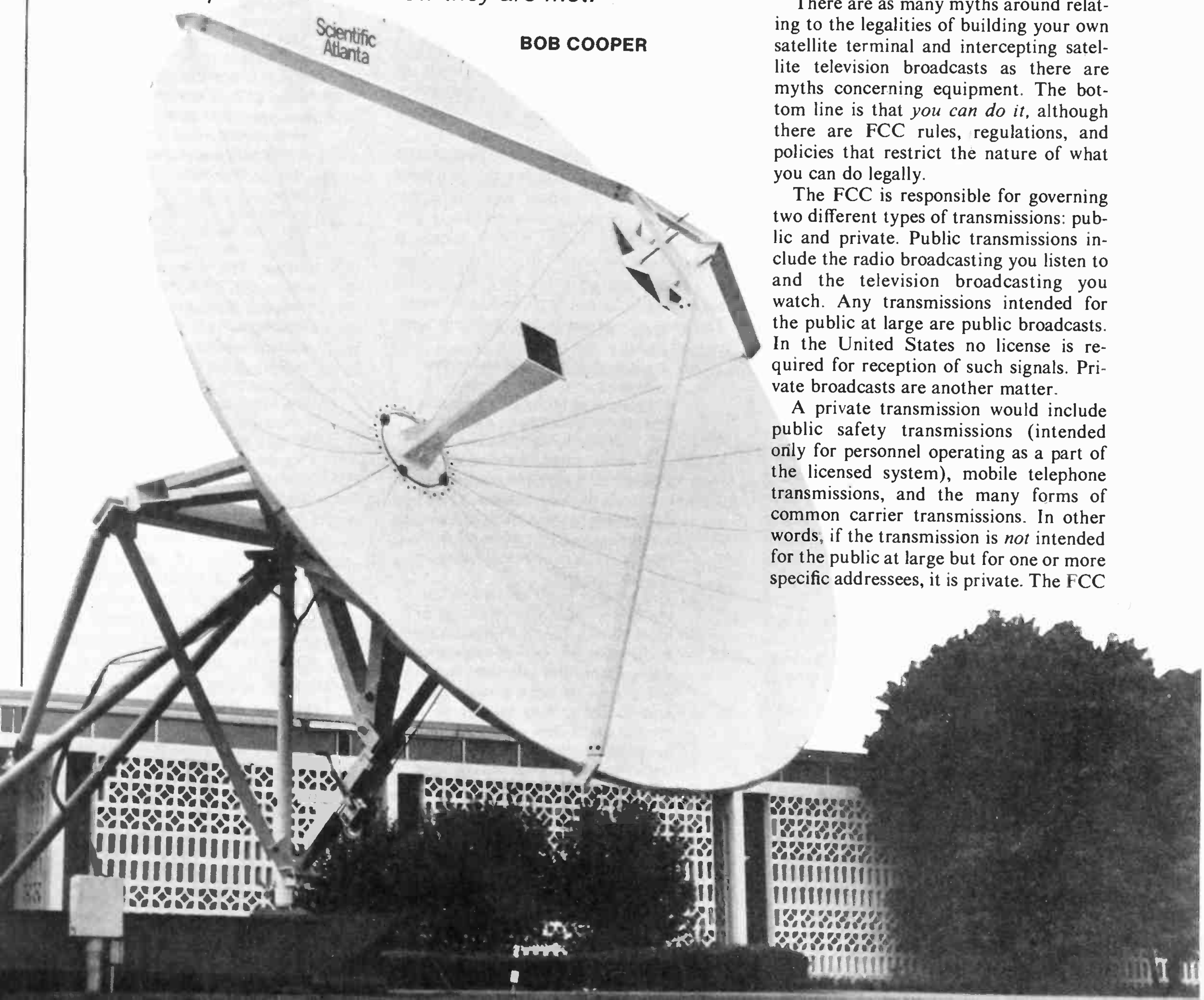
Let's leave you with this bit of reassurance. If you sat down with an order form from established, reputable manufacturers selling hardware to the CATV (etc.) commercial users and bought everything you need for this type of reception already assembled (you would do the actual installation), you could buy everything necessary for 48-dB video signal-to-noise-ratio reception for less than $5500. And that includes a 24-channel tuneable receiver.

While a far cry from the $100,000 early turnkey cable systems of 1975, it may still be too rich for your blood. So, let's add this postscript: If you built your own antenna and LNA, and assembled your own receiver from prewired and tested modules, it would cost about $3000. Still too much? Here's the bottom line for this month: A California hobbyist assembled his own system for under $1500, using lots of ingenuity and a good knowledge of surplus equipment. And a fellow in Sheffield, England, built his private terminal for under $1000. We'll dig into all this with some enthusiasm in a future article. **R-E**

Home Reception *via* SATELLITE

Part 3—This month we'll see where home satellites stand legally and then take a good look at the technical requirements and how they are met.

BOB COOPER



IN THE AUGUST AND SEPTEMBER, 1979 issues of **Radio-Electronics**, we learned that, through a network of largely non-affiliated geo-stationary communication satellites, multiple channel television is now available to virtually any point on the globe. Satellite television, using geo-stationary satellites, rises above terrestrial television in many ways. It is virtually immune to interference, does not suffer from lower atmosphere weather changes, and is of a technical quality that can only be approached (but not exceeded) by the ground-based microwave networks that link the cities of a nation together in a communications grid.

Now we are going to learn how this marvel functions, and how persons with some mechanical skills and ambition can put it to work for themselves.

The legal side

There are as many myths around relating to the legalities of building your own satellite terminal and intercepting satellite television broadcasts as there are myths concerning equipment. The bottom line is that *you can do it*, although there are FCC rules, regulations, and policies that restrict the nature of what you can do legally.

The FCC is responsible for governing two different types of transmissions: public and private. Public transmissions include the radio broadcasting you listen to and the television broadcasting you watch. Any transmissions intended for the public at large are public broadcasts. In the United States no license is required for reception of such signals. Private broadcasts are another matter.

A private transmission would include public safety transmissions (intended only for personnel operating as a part of the licensed system), mobile telephone transmissions, and the many forms of common carrier transmissions. In other words, if the transmission is *not* intended for the public at large but for one or more specific addressees, it is private. The FCC has rules and regulations, created from the broad authority given to the agency by the 1934 Communications Act, to help non-public transmitters keep their transmissions private. The strongest tool in that arsenal of bureaucratic mumbo-jumbo is something called Section 605, a portion of the regulations that deals with secrecy of communications. Section 605 tells us that private transmissions are intended for specific recipients and that if you are not a specific recipient you are not to "tune in." Section 605, also says that if you should happen to tune in (as in by accident) you are not to (1) divulge to anyone else what you have heard (seen), or (2) pass on to anyone else the fact that you have tuned in a private broadcast, and, (3) "profit" from the interception of the private transmission.

As a category, all common carrier transmissions are classified as private; and all satellites operate as common carriers. On the surface that sounds as if anyone who sets out to tune in satellite TV transmissions without the official permission of the transmission agent is acting in violation of Section 605.

Between the language of the 1934 law and the application of 1979 regulations there is a wide gap of practicality. As a practical matter much of what is transmitted via satellite is no more private than your local television station's programs. Signals such as WTCG, WGN and KTVU were broadcast signals before they became satellite signals. In fact they are taken out of the air (*i.e.* public domain) and sent via satellite. The FCC and others recognize that there is a wide gap between a set of rules based upon a 45-year-old law and the onrush of technology. At the present time the FCC is attempting to sort all of this out by proposing a new system that will eliminate the mandatory licenses that, up to this point, have been required of all satellite receive terminals. The Commission suggests a simple registration process with special dispensation for individual terminals constructed or installed by non-commercial entities. In the interim, a number of private terminals have been installed following something called the experimental/developmental licensing route[1] (I'm licensed as WF92) while many thousands more have simply been installed.

The basic terminal

Remember that we are dealing in satellite television reception with two technical parameters that do not coincide with our established VHF-UHF television system. We have a different frequency range for the transmissions, and we have a different modulation format. Both of those changes are evident as we review Fig. 1 which establishes what the basic terminal looks like.

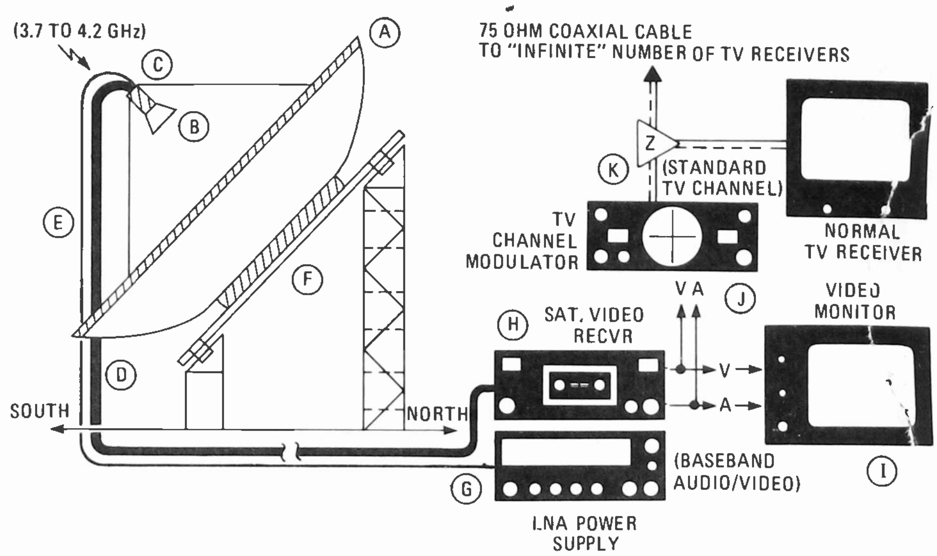


FIG.1—THE BASIC SATELLITE television receive terminal system. The 3.7 to 4.2 GHz satellite signals are received and focused by the parabolic reflector (A) to the feed or focal point antenna (B). The signals are amplified in a low-noise amplifier (C) and carried to the receiver in low-loss coaxial cable (D). The most common antenna mount is a "Polar Mount" (F) which allows side to side (azimuth) antenna movements from satellite to satellite. The 3.7 to 4.2 GHz satellite signals are processed and demodulated in a satellite video receiver (H). DC power for the low noise amplifier is fed from a separate power supply (G) through a dedicated weather protected line (E) to the LNA. Video/audio (baseband) from the satellite video receiver can be fed to a local video (audio) monitor (I), or to a RF (TV channel) modulator (J) which produces a standard NTSC (color) modulated signal at the modulator's design RF channel.

Our 4 GHz frequency band requires a different approach to antennas. We need a fair amount of signal gain since our satellite is operating at a relatively low power level (5 watts or +7 dBm). It turns out that with current technology the most cost effective way to acquire such gain is to use a parabolic reflector. The gain of a parabolic is dependent upon several factors:

1. The foremost factor is the antenna aperture or capture area. That is the surface area of the antenna that intercepts signals; each time the surface area doubles, the gain of the antenna increases by a textbook 3 dB. Remember that the area is the square of the surface region so it turns out that a physical size increase of 50% results in approximately double the surface area.
2. The second most important factor is the design of the feed or focal point antenna. The parabolic achieves its gain by capturing energy from the intended transmitter over its large surface area and focusing that energy to a central point. The actual pick-up antenna mounts at that (predetermined) focal point. The feed antenna will by necessity have a reception pattern of its own which means it "sees" the parabolic reflictor surface with varying degrees of efficency. To realize as much gain as possible from the full reflector surface the feed antenna must be carefully designed.
3. The feed must be sufficently broadband to cover the whole of the satellite downlink frequency band (3.7 to 4.2 GHz). That simply says that the antenna must work equally well throughout the whole of the spectrum.
4. The surface accuracy of the parabolic surface must be carefully controlled. In commercial antennas, the design criteria calls for surface accuracies of ±0.050 inches. That may be a little tight for a totally home constructed antenna although some builders have developed techniques[2] that assure accuracies in the ±0.080 region. When the surface tolerance varies too much, the gain of the antenna suffers. A 0.050 variation over the full surface can create gain-losses in the 0.5 dB region (off of maximum theoretical gain) while variations of 0.1 inches will result in gain losses of over 1.0 dB. If all of that sounds like not very much loss, think again.

The science of satellite reception is a very exacting one at its present stage of development. One of the mental hurdles you must adjust to is thinking in terms of 0.1 dB or 0.5 dB differences as being *substantial* differences.

The feed antenna signal is coupled

[1] The FCC will authorize experimental/developmental class licensing for TVRO terminals established for the purpose of equipment development testing. The author, and others with an interest in developing the technology base of the service, have followed that procedure to obtain one-year, renewable licensing in this service. An "Experimental Terminal Licensing Guide" is available from TPI, Suite 106, 4209 NW 23rd, Oklahoma City, Ok. 73107. Enclose payment with order.

[2] A complete textbook on building your own 16 foot aperture TVRO antenna using readily available hardware store supplies is available from PARAFRAME R & D, P.O. Box 423, Monee, Illinois 60449 (312-534-7435). That antenna has been developed primarily for duplication by private terminal enthusiasts and the manual includes step-by-step construction details including full parts sourcing.

directly into a low noise amplifier (or LNA, as it is known in the trade). That is simply a signal booster, not unlike the antenna mounting signal boosters used for fringe area terrestrial TV. However that is where all similarities cease. The LNA is rated by its gain and by the noise factor (*i.e.* noise figure). Gain is important, but that is secondary to the noise figure of the unit. To achieve the kind of noise figures required to produce high quality television pictures we have to push the science of transistor technology to its very uppermost limits. The latest thing in low noise transistors for the 4 GHz frequency range are GaAs-FET's: Gallium Arsenide Field Effect Transistors. The latest of these devices are capable of creating noise figures in the 1.2 dB region. However there is a price for such low noise at 4 GHz: money. The transistors available for this application are in short supply (although it is improving rapidly) and that keeps the price up. A per-transistor-price of $200-$300 is not uncommon and a pair in that range are typically required in commercial LNA units.

There is another way to go here; to lower the costs, the system designer can trade antenna size for LNA noise figure. By using less expensive front end transistors and a slightly larger antenna, the home builder can shave large dollar numbers from the terminal cost as we shall see.

In a commercial installation, the LNA is connected to the receiver through a length of low loss coaxial cable. If you are into cable, you should suspect that at 4 GHz regular coaxial cable is a disaster; RG8, 11, or other cables (including even the CATV type aluminum sheathed cable) have very high losses at that frequency. Therefore you graduate to more expensive cables with larger diameters and lower loss. The most commonly employed cable for this application is the *Heliax* or spiral-air insulated line. Losses in 100 fet are in the 4-6 dB range at 4 GHz and that can usually be tolerated.

The receiver can be called a demodulator since it actually takes the 4 GHz input signal and through a series of steps translates the RF signal down to baseband video and audio. Receivers in the commercial area are available in either single channel or tuneable formats.

The LNA must be powered and the most common power source is a DC supply in the 12-18 volt region. Normally a power line carrying that operating voltage is run from the inside location to the antenna where the LNA mounts. The current requirements are minimal (150-250 mA being typical) although voltage transients are a problem since the GaAs-FET's tend to be easily destroyed by spikes. Therefore many LNA supplies are Nicad cells constantly under trickle charge with the LNA connected to the battery bank that acts as a "sump" for primary line voltage transients.

Because we cannot convert the FM/FM format to a standard TV receiver IF and then to video/audio, the output of the satellite video receiver is baseband audio and video. To view this signal requires a separate box or series of boxes. For the highest quality local viewing most systems have one or more studio-type color video monitors. Such monitors are expensive, but with extremely high signal to noise video coming out of the satellite receiver (50-55 dB signal to noise is the range we are dealing with) the end result (the picture) is enhanced by this approach. That's fine for on-site viewing, but not practical for multiple viewing locations. Therefore most often the baseband video/audio signals are looped to a TV RF modulator operating on some specified TV channel. Modulators come in all shapes, sizes, and price ranges, running the gamut from single transistor oscillators to complex mini-broadcast stations with separate audio and video modulation controls, aural to visual carrier ratio controls, peak white limiting, and a host of other professional features. Once we've fed the satellite baseband signals to a TV RF modulator the signal may be carried on through standard 75 ohm coaxial cable (as found in MATV, CATV and home cabling projects) to an infinite number of standard TV receivers.

The parabolic antenna

The antenna does two important things for the system:

1. It provides the necessary signal gain to produce a 4 GHz signal level of sufficent intensity to create an interference-free picture, and,
2. It provides a way to discriminate (separate) between the desired signal and others operating in the same frequency range that are not desired at that moment.

If you could stand off to the side of the earth, as depicted in Fig. 2, and look at a cross section of the earth plus the geo-stationary satellite belt, you would notice that for locations north of the equator the satellite antenna has to look "downhill" to see the satellite hovering above the equator. For a satellite terminal directly on the equator, the satellite is overhead. For locations north of the equator, the satellite is progressively lower and lower to

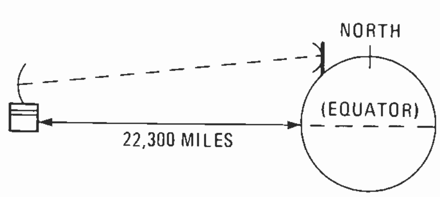


FIG. 2—THE GEOMETRY of the earth-space-earth system. The geo-stationary satellite is positioned directly above the equator approximately 22,300 miles. The satellite is maintained in a "station-keeping" box approximately 70 miles on a side by earth controllers.

our
nor
recei
inclina
at the ho
inclination w
straight up would
nation. For most of North
inclination is between 50 degree
eventually 0 degrees at the 80
parallel. By placing a protractor
finder) parallel to the flat back surface the dish and measuring the inclination (or elevation angle as it is also known) you can adjust the angle to match the desired angle. A computer chart that spells out the elevation angle, azimuth angle (left and right), and distance to all visible geo-stationary satellites from your location is available.[3]

Rather than standing off to the side of the earth, if you moved to a point directly above the north pole and looked down at the earth and the circular orbit belt surrounding the earth you'd get a view similar to Fig. 3, which shows only the six television carrying satellites presently in service for North American domestic relay. By international agreement the orbit belt from 70 degrees west to 140 degrees west is set aside for North American domestic relay satellites. Also by international agreement all such satellites are required to maintain a 4 degree spacing between themselves, as a minumum. For example, SATCOM II is located at 119 degrees west while WESTAR II is located 4.5 degrees further west at 123.5.

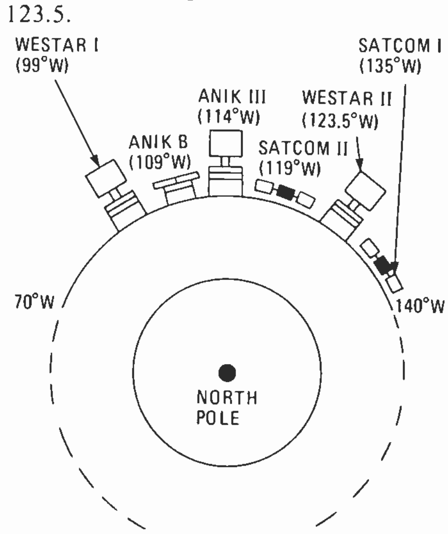


FIG. 3—THE SATELLITE geo-stationary belt as seen from a position directly above the north pole of the earth. U.S. and Canadian "orbit belt" extends from approximately 70 degrees west to 140 degrees west longitude. From your location a satellite due-south of you will appear highest "in the sky" while satellites east or west of that point will gradually be closer and closer to the "horizon" as their longitude differs more from your own.

[3] A highly useful computer derived chart that locates every geo-stationary satellite location that is within "line of sight" of your location is available. Enclose your geographic coordinates (longitude and latitude with degrees and minutes) and order from TPI, Suite 106, 4209 NW 23rd, Oklahoma City, Ok. 73107.

has rules and regulations, created f; to the broad authority given to the ag,rds by the 1934 Communications Act, tearth non-public transmitters keep theias "no missions private. The stronger a whop- that arsenal of bureaucratice. Naturally, bo is something callewas on the books portion of the cost a bundle, $100,000 secrecy ocal.

tells urly 1976, I conducted tests to intermine just what type of service might yo practical with smaller antennas and determined that antennas down to at least 4.5 meters (15 feet aperture) provided adequate service and that such antennas were not bothered from interference created when two adjacent-in-orbit position satellites were operating at the same time on the same transponder channel. Those tests were refined and submitted to the FCC in the form of a Petition for Rule Change and in late 1976 the FCC changed its rules and allowed antennas smaller than 9 meters (down to 4.5 meters) to be licensed for satellite receive terminal purposes.

There is, however, a substantial difference between a commercial terminal and a private (non-commercial) terminal. It happens that the FCC, in granting licenses for commercial terminals insists that these terminals maintain an "excess signal margin" of nearly 3 dB. What is an excess signal margin? The FCC says that when you design a receive terminal you will marry together the gain of the antenna, the known or predicted signal contour of the satellite being licensed for, the noise figure (and gain) of the LNA, and the receiver parameters to compute what your ultimate signal-to-noise figure at baseband video will be. As an applicant for the service you submit those calculations to the FCC as part of your license application. The rules state that if your calculations show the "threshold of noise" to be at the 48 dB signal-to-noise point (that is where it typically falls) then your terminal must have approximately 3 dB *more signal* than is required to attain the 48 dB ratio as a safety margin. It turns out that the 3 dB "excess signal margin" can be very expensive.

We've alluded to "signal contours" from the satellite several times so far. What happens is this: The output power is 5 watts per transponder channel. That output power is coupled into a directional antenna on the satellite and the directional antenna has lobe characteristics, like any other terrestrial directional antenna. Dead in the center of the pattern, where maximum gain occurs, is called "boresight." Off boresight the gain of the transmit antenna falls off and therefore the signal level on the ground becomes lower. Refer to Fig. 4 which shows a typical antenna EIRP (Effective Isotronic Radiated Power) contour pattern from an operating satellite. The strongest signal levels are found within the 36 dBw portion of the coverage, while lower signal levels prevail in the 35,34, etc. contour circles or ellipses. Sets of those maps are available for the primary domestic satellites in operation.[4]

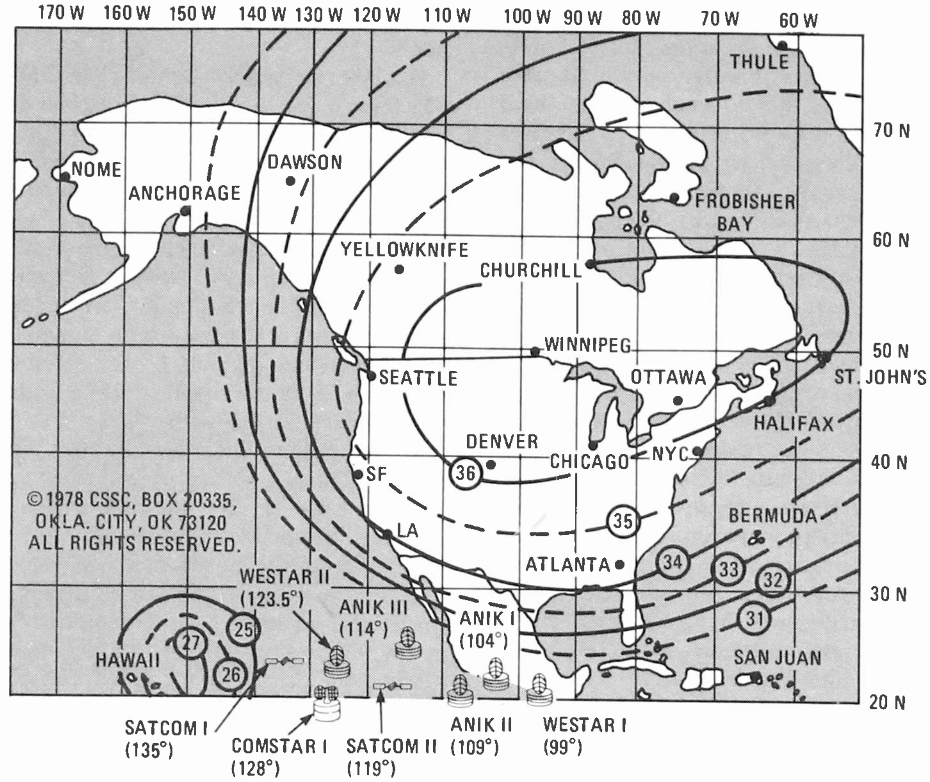


FIG. 4—SIGNAL LEVEL CONTOUR MAPS are called EIRP Contours. The output power of the satellite transponder (typically 5 watts) is converted to decibels above one watt (*i.e.*+7dBw) and is added to the gain of the transmitting antenna. If the antenna gain is 29 dB at boresight (center of the pattern) the radiated power becomes 7 + 29 or 36 dBw EIRP.

The trade-offs

It turns out that there are several combinations to get the same signal to noise ratios. We speak of measuring signal to noise as a baseband measurement function. There are other ways to measure the system but that turns out to be the best system for repeatable apple and apple measurements, since we are dealing here with the final result of the whole system: the quality of the picture (and audio) as measured at the receive terminal.

Here are ways to increase the baseband signal to noise ratio at a location with a given signal contour (EIRP):

1. Make the antenna gain larger
2. Lower the noise figure of the LNA
3. Reduce the bandwidth of the receiver (by progressively sharpening up the IF bandwidth, ahead of the discriminator/demodulator)

Now if in a given (36 dBw EIRP) contour area calculations show that to license the terminal commercially you must employ a 4.5 meter (15 foot aperture) antenna plus a 150 degree Kelvin[5] LNA with a 30 MHz IF bandwidth, what would it take to produce not the FCC mandated 51 dB (48 plus 3) signal to noise ratio but rather a more modest (for private use) 48.5 dB signal to noise?

The antenna could be reduced to 3.0 meters (10 feet), or, the LNA could be replaced with a 300 degree Kelvin unit. Or, you could narrow the receiver IF to 15 MHz rather than 30 MHz, go to a ten foot aperture antenna and get by with a 180 degree Kelvin LNA.

The antenna gain and the LNA noise figure can be played back and forth directly without many side effects. Make the antenna larger, use a lesser quality LNA. Make the antenna smaller, use a better quality LNA. There are limits, of course (an 8 foot dish is about as small as you can go even in high EIRP areas and still expect a high quality signal.) The receiver IF trade-off is one of those areas that begs for additional well documented exploration. The transmitted bandwidth is nearly 36 MHz. However, most commercial receivers are employing 30 MHz IF bandwidths because they gain a bit in signal to noise that way without degrading the baseband video quality. Tests conducted by myself, and others, indicate that the 3 dB bandwidth points of the IF can be narrowed to 15 MHz on highly critical transmitted material, such as color bars, and the human eye cannot tell

[4] A set of 11 satellite EIRP maps is available covering SATCOM I (4 maps), SATCOM II (4 maps), WESTAR I and II and ANIK III (1 map each) from TPI, Suite 106, 4209 NW 23rd, Oklahoma City, Ok. 73107. Enclose payment with order.

[5] The science of noise figure measurement in the satellite equipment area is very sophisticated. LNA noise figures are measured by using the Kelvin (K) temperature scale with 0 degrees K being a no-noise source and higher K numbers indicating amplifiers with progressively higher noise figures. Certain benchmarks are: 1.0 dB noise figure is 75 degrees K, 1.5 dB noise figure is 120 degrees K, 2.0 dB noise figure is 170 degrees K, 2.5 dB noise figure is 225 degrees K, 3.0 dB noise figure is 290 degrees K and 4.0 dB noise figure is 435 degrees K.

that the picture quality has been degraded. Yes, on a waveform monitor you can begin to see some telltale signs of waveform distortion but to the eye that distortion is not yet apparent.

You can afford to engage in trade-offs because we are dealing with an extremely stable signal environment. In spite of the FCC's mandated 3 dB excess signal margin for commercial terminals (they say that is to protect the viewers connected to commercial terminals in case there are a series of simultaneous system degradations), numerous chart recorder tests indicate that worst case signal variations over a full year's term should amount to less than ±0.7 dB of the nominal value. This suggests that once you attain performance that is above the noise threshold, you are "home free." This would be a good time to explain why you don't have the luxury of watching "slightly snowy pictures" with this service.

Noise in the picture disappears when the carrier level reaches a point where the receiver is into limiting. A 48 dB video (baseband) signal to noise actually indicates a carrier to noise (at 4 GHz) of perhaps 11 dB. In other words, if the carrier is 11 dB higher than the noise at 4 GHz you will have a 48 dB signal to noise ratio at baseband after demodulation. That incredible performance is made possible by something called the "FM Improvement Factor." In this service, with the bandwidths employed, it amounts to a healthy 37 dB (plus change). You can compute video signal to noise ratio by taking the FM improvement factor (call it 37 dB) and adding to that the carrier to noise *ratio.*

By now, you must be impatient to know (based upon your having spotted your own location in Fig. 4) just what type of equipment you might require at your own location to get *48 dB signal to noise ratio service*. Some rough guidelines, subject to refinement, is shown in Table 1.

TABLE 1

EIRP Contour	Antenna Size	LNA Required
36 to 37	20 foot	600°K
	15 foot	300°K
	12 foot	200°
	10 foot	120°K
	8 foot	100°K
34 to 36	20 foot	300°K
	15 foot	200°K
	12 foot	120°K
	10 foot	90°K
32 to 34	20 foot	200°K
	15 foot	120°K
	12 foot	90°K
30 to 32	20 foot	120°K
	15 foot	90°K

These are meant to be guideline numbers and are subject to some refinement since the system designer works with factors such as receiver IF bandwidth (30 MHz is assumed in the above), antenna elevation angle (low angles start to become noisy) and so on.

If you miss the suggested goal by a small amount you can live with the result, which will be slightly noise marred pictures. Noise is more evident on a static picture (*i.e.* color bars, identification slide) than it is on a moving scene. In practice, if you are 1-4 dB *below* threshold you can sit and enjoy the picture and proudly show it off. It won't have that network-control-room look, but you'll be pleased with the results.

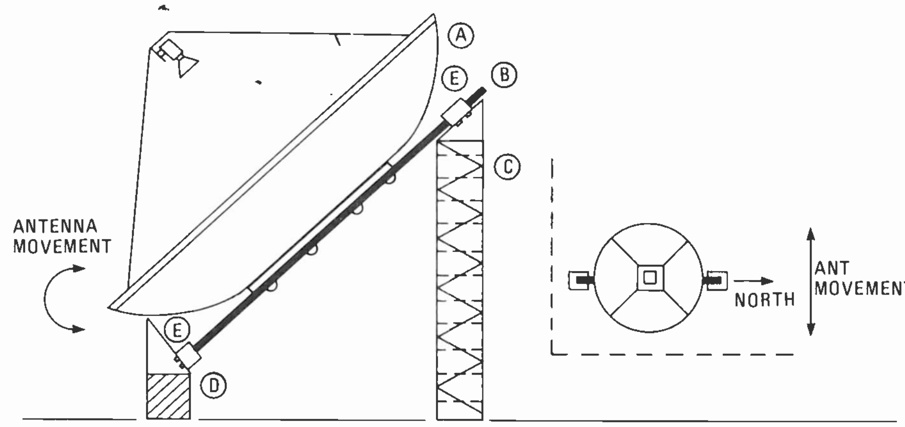
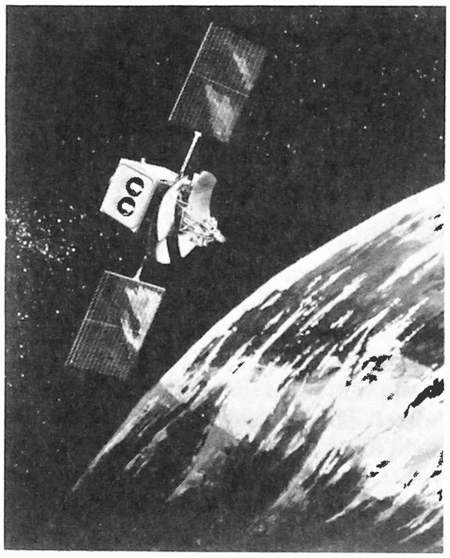


FIG. 5—POLAR MOUNT MECHANISM requires system that suspends the reflector surface (A) on an axle (B) suspended between two supports (C) (D). The axle "floats" in some type of thrust bearing collar (E) on both ends of the axle at each support. The taller of the two supports is the "north" end while the shorter is the "south" end. Supports (D) and (C) are spotted on the ground so that they fall precisely (within 0.1 degree true after magnetic correction) on a north-south line. The height of the shorter support is determined by the amount of azimuth play you wish built into the system. To be able to turn the surface from horizon to horizon requires a height at (E) at least equal to 50% of the diameter of the dish. The height of the taller support (C) is in turn determined by the height of the shorter support, and, your latitude. The farther north you are located, the taller the north-end support so that at the line-of-sight limit (80 degrees north latitude) the reflector surface sits virtually at right angles to the ground and points at your horizon.



ARTIST'S CONCEPT of the Satcom III satellite that will be launched in December 1979.

The polar mount

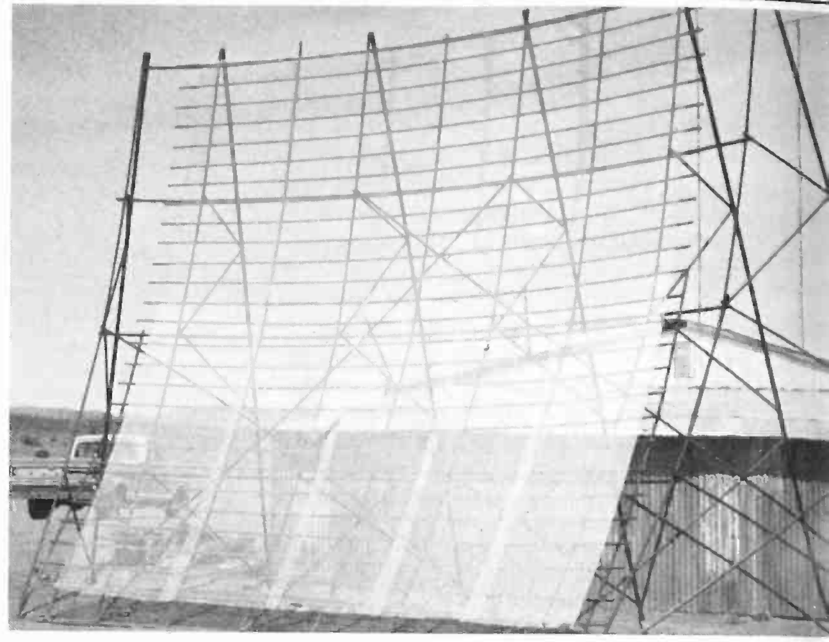
Recall that our satellites are "stacked" horizontally along an imaginary line called the satellite belt. Within the control parameters, they are stationary inside of a 70-mile by 70-mile by 70-mile cube or box, which from our distant earth point means that they move so slightly that we won't notice the movement.

The geo-stationary belt reaches its maximum elevation for our own location at a point due south. By using the charts available[3] we can determine how much elevation to adjust the antenna to for each of the locations where the satellites rest. This means that if you wish to move from one satellite to another, you would have to adjust the antenna elevation (angle of inclination) and *also* adjust the antenna's boresight (azimuth). These are two separate adjustments that interrelate. You might have the right boresight heading (azimuth) but if you have the incorrect elevation you won't see the satellite, and vice versa. There are many commercial antennas that use this type of mount adjustment system (called an Az-El as in azimuth over elevation) and for those installations where satellite changing occurs infrequently it is an acceptable system.

There is a better system, however, for frequent satellite change; see Fig. 5. The Polar Mount consists of a long axle on which the reflector surface is mounted, with the axle suspended in thrust bearings at each end. The thrust bearings or collars are in turn mounted on inclined surfaces, as shown with the south support stub quite short while the north support is fairly tall. The angle of the axle is your elevation angle for your particular location and, as you can see by dropping the short stub and/or raising the height of the north support, that angle can be fine-tuned for your particular latitude.

Now it happens, as a wonder of celestial mechanics, that if the two supports for the Polar Mount are fixed on the ground on a true north-by-south line and the inclination angle is adjusted for a true southerly heading so that, from that point onward, the Polar Mount will track across the geo-stationary orbit belt without additional adjustments to the elevation. That makes a very nice system for frequent satellite changes since the adjustments are now limited to one direction (left or right). **R-E**

Home Reception Using Backyard Satellite TV Receivers



SWAN SPHERICAL ANTENNA is effective in receiving satellite transmissions and can be built relatively inexpensively.

Part 4—In this installment of a series, we will go into more technical details on receiver characteristics and specifications and will show how some satellite receivers have been built at comparatively low cost.

ROBERT B. COOPER, JR.

IN PARTS ONE, TWO, AND THREE OF THIS multiple-part series (appearing in the August, September, and October 1979, issues of **Radio-Electronics**) we learned how the geo-stationary satellite system is designed, what it is intended to do and what a private individual, living someplace south of the 80th north parallel, north of Venezuela, and east-west between Bermuda and Hawaii can anticipate being able to receive with a private, backyard satellite television terminal. Satellite television is the next "generation" of television service in America and throughout wide areas of the world. Because of the mechanics of the service, it is virtually immune to interference and signal degradation, is not adversely affected by weather, and holds the potential to provide every home in North America with several hundred direct-access television channels!

Receiving system

Having determined that the basic system consists of an antenna, a low-noise amplifier (LNA) and a receiver-demodulator, let's look at what it is that goes into each of these three major component modules to make up the operating system.

The antenna system has been adequately covered in previous portions of this series. Basically, in order to achieve the kind of gain necessary (38 to 45 dBi) a parabolic reflector is the best antenna choice. This parabolic reflector has a single focal point where all of the energy intercepted by the reflective antenna surface is re-directed and focused. There are several acceptable members of the antenna family known as parabolics that can be pressed into this service: prime focus parabolics, Cassegrain parabolics and spherical parabolics are included. For as long as the (limited) supply holds out, surplus (as in no longer used in commercial or military service) parabolic (or "dish") antennas larger than 8 feet in diameter provide very economical "reflector surfaces" for most portions of North America. The exception to this is in New England where anything smaller than a twelve-foot reflector surface would be a mistake. Beyond that, one of the least expensive antenna surfaces for this service has been developed by a fellow in Arizona named Oliver Swan. Using aluminum window screening as a reflector surface, and stock square aluminum or steel tubing as reflector frame material, Swan has developed a spherical antenna system that can be constructed in virtually any size from 10 feet by 10 feet to 20 feet by 20 feet for as low as approximately $500 for the ten-foot by ten-foot version. It is inevitable that some commercial firm will soon begin marketing antenna "kits" in this area, perhaps copying the Swan developed spherical antenna and that from this will spring a whole new family of "backyard decorative pieces."

Because we are dealing with a low-power transmitter source (the typical satellite has a 5-watt peak power transmitter) and a fairly high loss between the "bird" and your receiving location (196 to 200 dB is typical at 4 GHz), not very much signal power arrives at your antenna. Fortunately, the signal received is very constant (variations of $\pm$ 0.7 dB over a full year are typical limits) and this allows us to design the system for peak performance and forget it rather than be concerned with wide-range AGC systems to cope with large signal fluctuations.

To make the most of the weak signal, we have to place a very high gain, and extremely low noise (figure) signal amplifier (or booster in TV terms) right at the antenna. Since the reflector surface on the parabolic is merely a focusing tool, the actual "pickup antenna" is really separate and distinct from the reflector. This receiving antenna, directed backwards away from the satellite and towards the focused energy coming from the reflector surface, is called a "focal point" or feed-point antenna.

The most efficient feed antenna is one that looks at the reflector surface in such a way that the "pattern" on the feed antenna is down 10 dB at the out-

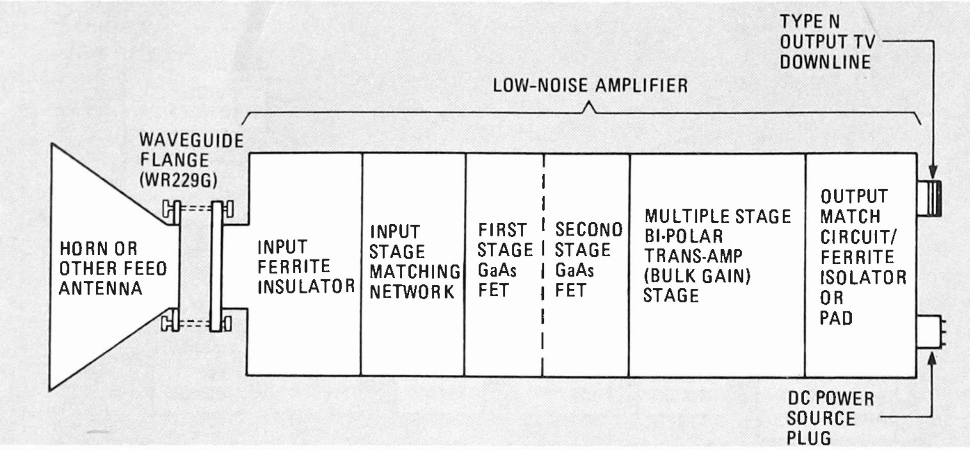


FIG. 1—MOST COMMERCIAL FEED-ANTENNA LOW NOISE AMPLIFIERS consist of a feed antenna (often a horn as shown for a prime-focus feed) which is equipped with a waveguide flange that bolts it directly to the input flange on the LNA (*Low Noise Amplifier*). The LNA has an input (ferrite) isolator both for frequency selectivity and as an impedance matching device for the first stage of the amplifier itself. The extremely low-noise amplifiers develop their superior operating characteristics because of extreme care taken in matching the first stage to the input source impedance and by carefully hand selecting the expensive GaAs-FET (Gallium Arsenide Field Effect) transistors. GaAs-FET devices are chosen for the first two stages. Once the noise figure is "established" by these two stages, less costly bipolar transistors are used in 3-4 additional stages for "bulk" gain. The output, to the low-loss downline coaxial cable, is through another ferrite isolator device or through a "loss pad" inserted to force an impedance match.

side edges of the reflector's surface area. A horn-feed antenna, properly designed, handles this function. Look closely at Fig. 1. Note that the horn-feed antenna is flanged or bolted directly to the low-noise amplifier itself; the energy from the horn feed-point antenna couples through the waveguide flange into the input circuit on the low-noise amplifier, a section that has a piece of ferrite (rod) in it as an isolator.

Low-noise amplifiers

This commercial style low-noise amplifier is the state-of-the-art high-dollar approach to the low-noise amplification aspect of the system. There are less expensive ways to go as we shall see in subsequent portions of this series. The purpose of the ferrite isolator is primarily to insure that the input circuit to the first active (transistor) amplifier stage sees a constant impedance or load. This is done to insure that the transistor used in the first stage, a GaAs-FET (for *G*allium *A*rsenide *F*ield-*E*ffect *T*ransistor), is noise-figure matched at the 4 GHz operating frequency. Most of the high-dollar GaAs-FET's available for this service have two separate peak operating points; maximum gain does not coincide with best (i.e. lowest) noise-figure performance. In this case, gain is backed off in the first couple of stages as a trade off for lowest noise figure since noise generated in the early pre-amplifier stages is impossible to eliminate later on in the system.

Most of the commercial LNA units employ a pair of ultra-low-noise GaAs-FET's in the first two stages, and then follow that up with between three and five less expensive (typically bipolar as opposed to GaAs-FET) amplifier stages. Once the noise figure for the LNA is established by the first couple of stages, less expensive (and higher noise figure) bipolar stages can make up the remainder of the LNA system gain required.

Noise figure is measured in both dB and by the Kelvin noise temperature scale. Most of the commercial data sheets will specify Kelvin temperature only and most commercial installations are using amplifiers with 120-degree Kelvin (or 1.5 dB noise figure) specs.

State-of-the-art has been catching on quickly in this field; in late 1976 the price for a 120-degree Kelvin LNA was in the $3,500 region. By late 1978 you could find the same amplifier for around $1,800. Today the price is down in the $1,000 region and many expect it to drop down close to $500 by this time next year. That still may be high for your pocketbook and there are other options.

As previously discussed in this series, you can get a raw signal input to the receiver by one of two techniques; use a big antenna and an LNA with not such hot specs, or, use a smaller antenna and a hot-spec LNA. If you set out to build your own antenna system, rather than buying commercially, you might be better off in this fast-changing technology time to invest in a little more steel and mesh and build a larger antenna going in, especially if you plan on having to purchase your LNA.

As recently as early in the past summer anyone who wanted to build his own LNA was pretty much stuck with working with 300-degree Kelvin type bipolar transistors. The belief was that any home constructor attempting to work with the touchy, and hard-to-make-work GaAs-FET amplifiers was probably asking for a quick way to lose a $100 bill; that being the going price for the GaAs-FET transistors these days from Hewlett-Packard (HFET 2201). However, during the recently completed Satellite Private Terminal Seminar this past August 14-16 in Oklahoma City, several home terminal builders demonstrated two- and three-stage GaAs-FET amplifiers they had constructed for between $225 and $350 that gave an excellent account of themselves against commercial amplifiers costing three to four times as much. This major achievement has changed the name of the private or backyard terminal game for the home constructor.

Well now; if a chap in Arizona can build a 10-foot by 10-foot spherical reflector and feed for $500 or less, and you can build your own GaAs-FET low-noise amplifier on the kitchen table for $350 or less, that starts to get the home-constructed terminal down to an affordable price does it not? What about the receiver?

Receivers

In 1976 the first satellite video receivers around came into the cable television field via the Intelsat or international satellite marketplace. They cost upwards of $10,000 and were literally hand wired and hand aligned.

By early 1978 the price for essentially the same receiver was down to about half that; perhaps $5,000. But there had been only minor changes in the original design. The price reductions were largely due to slightly more volume production, and of course competition.

Needless to say many people were working on bringing the cost down; way down. Most however were involved in the cable TV, broadcast TV and other commercial market areas where nobody really expected receiver prices to drop much below say $3,000 for many years to come. Outside of these broadcast related industries other engineers with a totally different set of markets in mind were quietly doing their own developmental work. Their goal was a *$3,000 complete terminal;* including the antenna and the LNA.

By mid-1979 some inter-receiver marrying had taken place. Commercial receivers are available in two formats; some tune only one channel and to change channels you have to either change crystals or go through some sequence of screwdriver adjustments, or both. Not exactly what the home viewer accustomed to detent tuning has in mind. The other commercial receiver format is called "frequency agile" and that means you push buttons or twirl a knob and the full set of 12 (or 24) satellite channels flips by in front of you. By mid-1979 some of the commercial receivers in the single channel format were down under $2500 list price while the tuneable versions were just a tad above $3,000.

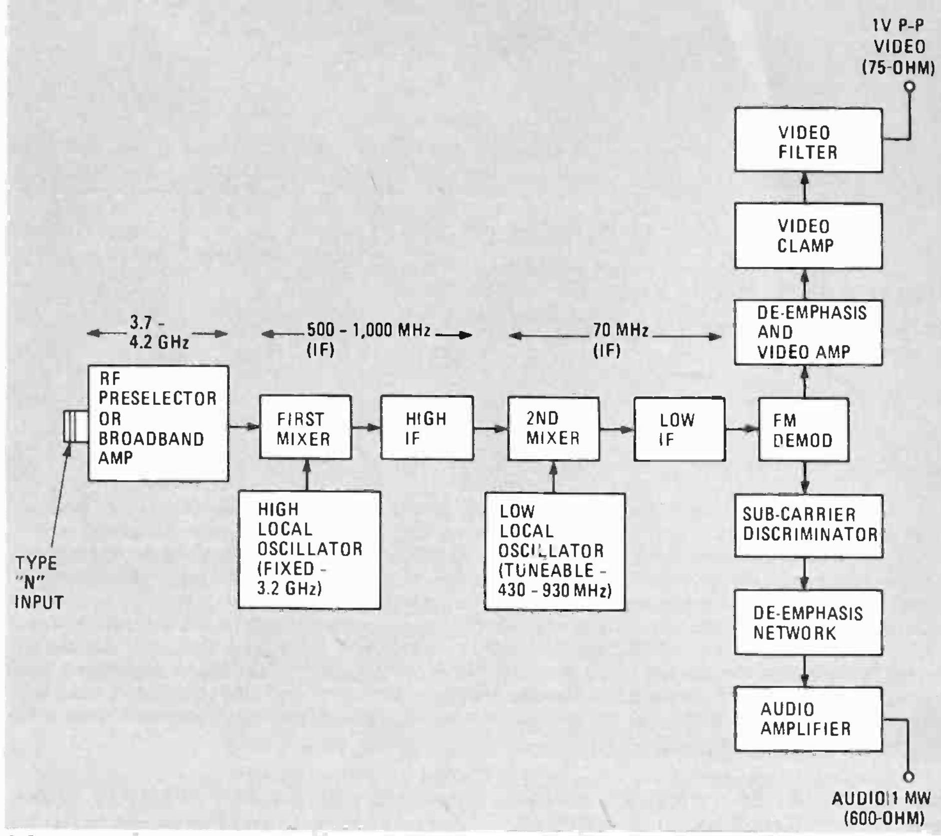


FIG. 2—MOST COMMERCIAL RECEIVERS use high-gain (50 dB) LNA's mounted at the antenna capable of driving 4-GHz region signals through several hundred feet of 7/8ths inch line to the indoor receiver. Typical receiver has either double conversion (approach shown here) or single conversion directly to IF. In receiver design shown, a 3.7- to 4.2-GHz preselector often has enough gain to bring the input RF level up to an adequate voltage to drive the first mixer. Relatively high-level high-frequency local oscillator (3.2 GHz is shown in example) may measure +10 dBm or more. With local oscillator on low side, high IF of 500-1,000 MHz is attained to drive second mixer that down converts to 70-MHz low IF. Oscillator for second local oscillator is voltage- or capacitive-tuned to produce 70-MHz low IF with inputs over full 500-1,000 MHz range. FM demodulator (discriminator) produces basic baseband signal that processes up for video to a de-emphasis circuit and video amp, then to a video clamp to eliminate the 30-Hz energy dispersal waveform, and then to a filter circuit. Audio processes down through separate (6.8 MHz) discriminator, de-emphasis network and audio amplifier.

Let's stop for a minute and study Fig. 2. To appreciate what is involved in a satellite television receiver, we ought to understand what it has to do.

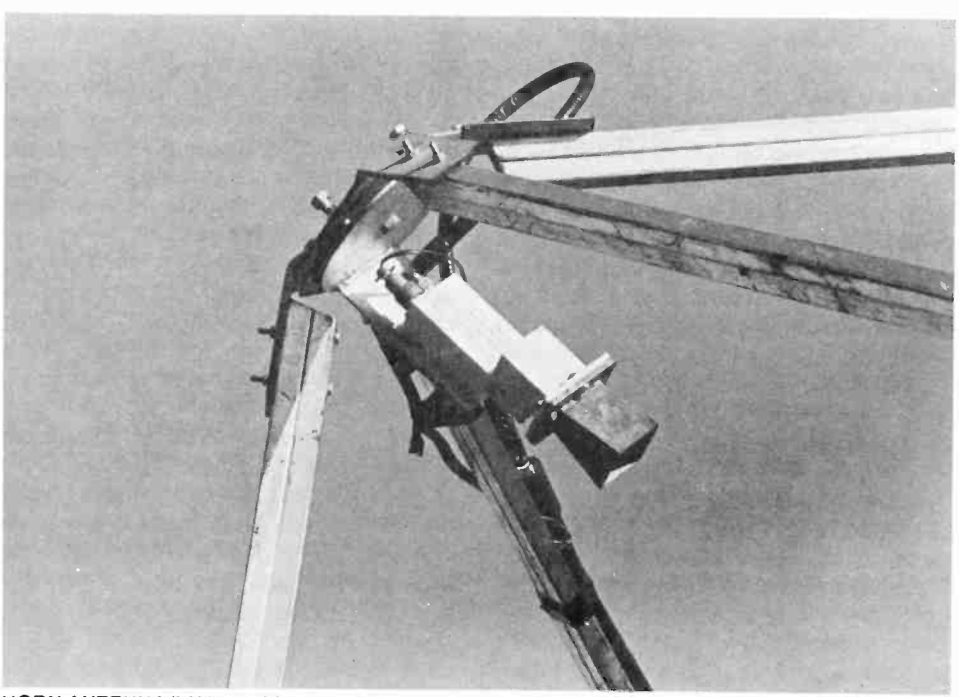
In a commercial installation the LNA (which mounts at the antenna, usually married to the feed-horn or focal-point antenna) has to develop sufficient RF signal voltage gain, at 4 GHz, to (1) drive the microwave signal through the interconnecting coaxial cable and into the receiver, and, (2) provide sufficient signal gain to establish the noise figure of the LNA as the noise figure for the whole receiving system.

The typical satellite TV receiver has a relatively high noise figure; 10-12 dB is not uncommon. To attempt to use such a high "front-end" noise figure to receive the weak satellite signals would be a mistake. To lower the noise figure to a more usable level (such as under 2 dB) requires not only a low-noise LNA but sufficient gain in the LNA stages to override the noise contribution by the 10-12 dB noise figure of the receiver. As a rough rule of thumb you need between 2.5 and 3 times as much voltage gain (in dB) as the noise figure (also in dB) to establish the new, lower noise figure of the LNA as the noise figure of the system as a whole.

Back now to Fig. 2. To keep unwanted energy out of the receiver (and there is plenty of unwanted or off-frequency energy floating around microwaves these days) the typical commercial receiver has a pre-selector (either totally passive or active plus passive) at the input. This is followed by a "high frequency-mixer" that combines the incoming (3.7 to 4.2 GHz) signals with a local oscillator signal source generated within the receiver to produce a new lower frequency (IF) output. Gain is then applied at the high-frequency IF and then the signal goes through yet a second mixer that further down-converts the high IF to yet a lower IF. This lower IF is often 70 MHz although there are some variations to this rule in commercial receivers. When we finally reach the lower IF, we have gone through a pair of down conversions each employing a high-quality mixer and a high-quality local oscillator. If this is a frequency-agile (i.e. tuneable) receiver the first mixer is driven by a tuneable local oscillator source while the second mixer is driven by a fixed local oscillator source. Just for dollar reference, we are looking at using $75 to $100 mixers in these applications and the local oscillators are priced in about the same range. If this suggests that microwave components or modules are not cheap, you read the message correctly.

Once at the low IF we are ready to go to work on the modulation itself. Gain at a relatively low IF such as 70 MHz is inexpensive these days and 40-50 dB of gain in this range is typical. When the twice-down-converted signal is built up to a sufficient voltage level, it is ready to be demodulated. Remember that the video is frequency modulated onto the carrier, and the audio coming along with the video is further frequency modulated as a sub-carrier. This says that we use discriminators to demodulate the video and the audio in our detection system.

By removing the video signal out of the IF signal with a detector, we end up



HORN ANTENNA/LNA combination points directly towards the dish antenna. Coaxial cable is used to connect the LNA to the receiver.

with what is called baseband; that means pure video in this case. Only because the audio is carried along as a 6.2- or 6.8-MHz add-on or subcarrier, when we demodulate to baseband video we also have a aural subcarrier in the baseband output. By using a low-pass filter for the video and a high-pass filter for the aural subcarrier, we can then separate the video into one chain for further processing and the audio into another.

The video is preemphasized at the uplink transmitter site as a means of increasing the system performance and at the receiver we need to deemphasize to establish the original baseband video characteristics. The deemphasis network is strictly an L-C network and is not complicated. Next in line for the video is a video clamp circuit that may mystify you if you are accustomed to normal video techniques.

Video at the uplink site is "frequency-dithered" or dispersed at a 30-Hz rate as a means of reducing potential interference between strictly terrestrial 4 GHz video circuits (such as the telephone companies employ) and the satellite service. The easiest way to clean up the dispersal waveform is to shove the video through a clamping circuit. If you clamp something like this *hard* enough, the 30-Hz waveform simply goes away. Finally a bit of passive video filtering and you are in business with baseband video (typically 1 volt peak-to-peak).

Over on the audio side, after passing the 6.2 or 6.8 MHz aural subcarrier through a frequency filter that eliminates the video baseband information, the signal is fed into yet another discriminator (detector) that recovers the audio. From here it goes through yet another deemphasis network (this one for the audio) and finally an audio amplifer. Most commercial receivers release the audio across a 600-ohm balanced output line.

If you are engaged in the television receiver servicing industry, you may be asking yourself why this should cost between $2500 and $3500 a pop. If you are new to receivers in general, you probably have the opposite reaction.

As we shall see in the next part of this series of articles, several experimental or private terminal builders have asked themselves the same thing. One terminal builder, Taylor Howard of California, has managed to assemble the LNA (a bipolar unit in his case) *and* the receiver for around $1,000. He did this back in 1976-77 when parts were considerably more expensive and we estimate you can do it today for under $700.

Assuming you don't want (or need) to start off with a bag full of new parts, and can assemble some equipment from other services into a satellite TV receiver, just how simple can it really be? Well, a man in South Carolina by the name of Robert Coleman has put together a 10-foot dish, a two-stage GaAs-GET LNA and a complete receiver for around $500! His "secret," if you can call it that, is that he is a sharp attendee of Hamfests and other outlets where *surplus* electronic equipment is brought out for sale at often just a few pennies on the original dollar value. The Coleman approach is a good one, but it requires being able to trace down surplus parts, modules and components that may not be a good supply because of limited production runs many years (or decades) ago. Still, if this approach does interest you and you are not afraid to go into the surplus market to look for parts, there is help available for you in this specialized area.

Suppose you wanted to try a cross between building a complete terminal receiver from scratch and assembling one from surplus equipment? Well, that is an approach many people have followed, largely patterned after the work done by English satellite TV experimenter/pioneer Steve Birkill (amateur G8AKQ). The Birkill receiver is similar to that shown in Fig. 3. The LNA is a bipolar system of three to five stages using Hewlett-Packard HXTR (6102 and 6101) transistors. For those who want to investigate this particular approach, Hewlett-Packard Application Note No. 967 tells how to build a stage of this amplifier at 4 GHz (a multiple stage-device is simply several separate stages cascaded together).

The Birkill Receiver places the LNA stages at the feed antenna, follows that with a double-balanced mixer (also located at or near the feed) and the mixer is driven by both the input 4 GHz range signal(s) plus a "free-running" oscillator operating at around 3,200 MHz. There are several ways to derive the local oscillator injection signal; one of the easiest is to use a completely self-contained oscillator. One of the 8360-family of oscillators manufactured by Avantek, Inc., 3175 Bowers Ave., Santa Clara, CA 95051 will do the job nicely. This TO-8 packaged device has four pins on it: one for the positive operating voltage, another for a ground, a third for the RF output in the gigahertz region and a fourth for a tuning voltage that allows you to run the oscillator through a 500-MHz span. Most homebrew (from

LEARNING MORE ABOUT SATELLITE TV

Readers with an interest in pursuing further the details of the Home Satellite TV Reception system may be interested in the following reference materials available:

Satellite Study Package—includes a 72-page "Handbook" describing the complete home satellite TV receiving system, how the satellites operate, where to locate equipment and what services are available via satellite, written by Bob Cooper. Also includes 22-by-35 inch four-color two-sided wall chart depicting each of the geostationary TV satellites in operation and explaining the technical equations of the satellite TV system. Satellite Study Package is excellent "starter set" towards a full understanding of the system and getting your own system underway. Price is $15 via first class mail (U.S. and Canada in U.S. funds) or $20 elsewhere from Satellite Television Technology, P.O. Box 2476, Napa, CA 94558.

Home Satellite Construction Manuals—three separate manuals available describing construction details (parts lists, sources for parts, schematics where applicable) of two separate receiver systems, low-cost low noise amplifiers and the unique new *Swan Spherical* TVRO antenna. The *Coleman TD-2 Manual* describes conversion of surplus microwave equipment to TVRO terminal plus showing latest low-cost methods of amplifying and converting 4-GHz signals to 70-MHz IF; the original Coleman system cost under $500 to build. The *Howard Terminal Manual* describes a 24-channel frequency-agile (tuneable) receiver plus bipolar LNA using off-the-shelf new parts that can be duplicated for under $800. Taylor Howard, a professor at Stanford, has had this system operational since 1976. The *Swan Spherical TVRO Antenna Manual* describes construction of a unique multi-satellite reflector surface plus a unique feed-horn; inventor Oliver Swan shows how a 10- to 12 foot-size antenna can be assembled with common hardware for under $300. Price of *each* manual is $30 or all three for $80 from: Satellite Television Technology, P.O. Box G, Arcadia, OK 73007.

Satellite Private Terminal Seminar—this past August more than 500 satellite TV enthusiasts attended first-ever "international seminar" as more than a dozen instructors (including Taylor Howard, Robert Coleman, Oliver Swan, and Paul Shuch) taught in classroom sessions the latest in low-cost satellite TV circuit technology. SPTS '80 will be held in Miami, Florida on February 5, 6 and 7 with special emphasis on how to market and install private low-cost terminals throughout North, Central and South America. There will be exhibits, live-satellite systems demonstrations, and course study books. Registration is $150 per person; advance registration required. For full information write: SPTS '80/Miami, P.O. Box G, Arcadia, OK 73007 or call (405) 396-2574.

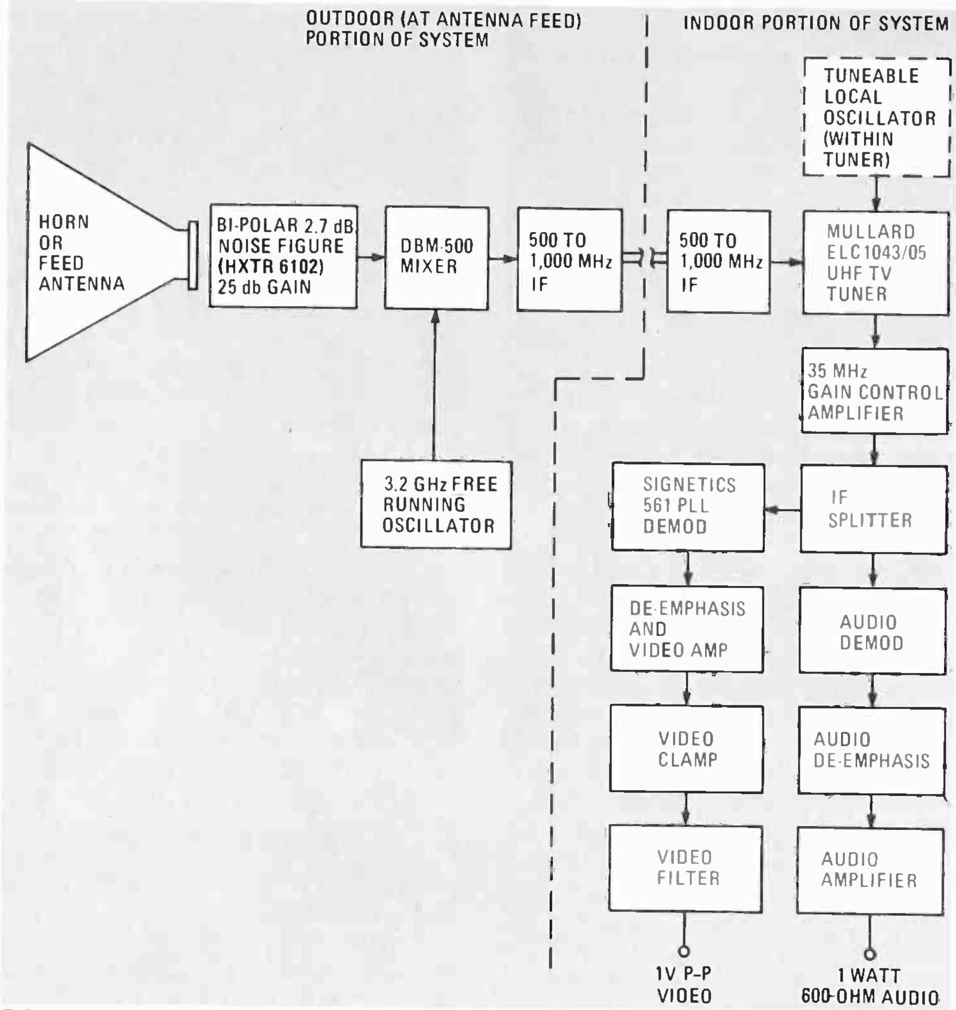


FIG. 3—MOST HOMEBREW TERMINALS place a lower grade LNA stage plus first mixer, local oscillator source and an IF stage or two at the feed antenna, coming down to the baseband demodulator through lower-cost 50-ohm cable at the high-IF (500-1,000 MHz) region. In this version, essentially patterned after English experimenter Steve Birkill, a Mullard ELC1043/05 (European) TV tuner is slightly modified as combination oscillator and mixer to translate high IF range down to 35-MHz region low IF. Birkill processes his 35-MHz IF to video through a Signetics 561 phase-locked-loop demodulator; a system that offers advantages for weak input level signals. Full block diagram is not shown at this time.

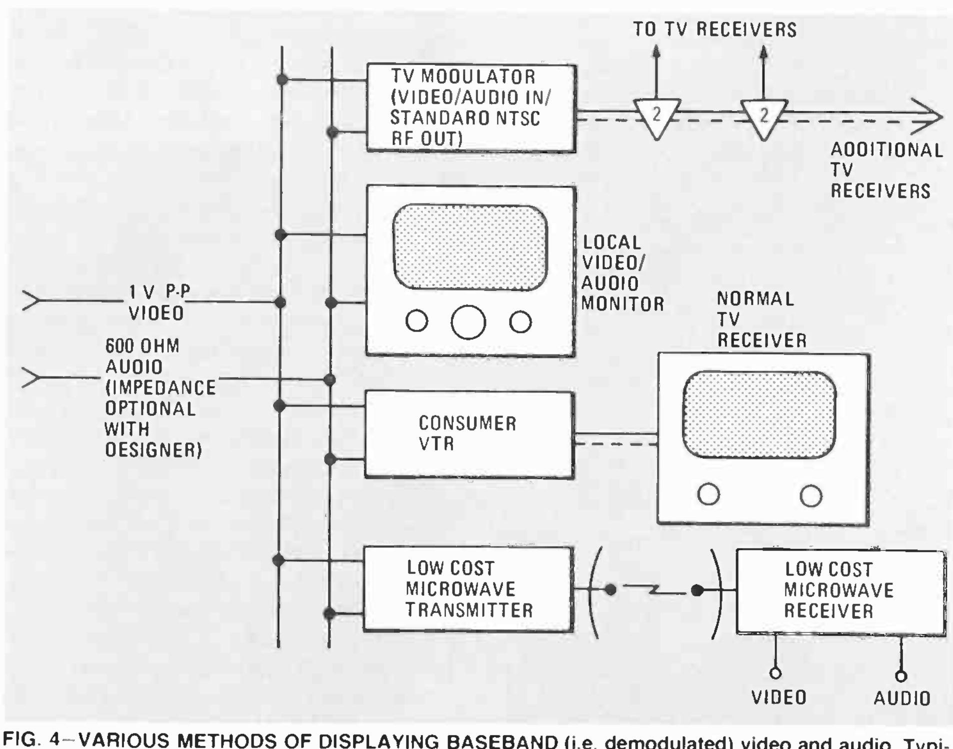


FIG. 4—VARIOUS METHODS OF DISPLAYING BASEBAND (i.e. demodulated) video and audio. Typical receiver produces 1VP-P video and some usable level of audio (often at 600-ohms balanced although that is design decision of builder). Baseband signals will directly drive TV channel RF modulator, a high-quality video monitor (with audio display system built-in or separate), a consumer VTR (for recording or as loop-thru to use RF modulator), or low-cost (private) microwave system.

scratch) satellite TV receiver builders are using this approach because it eliminates all work at microwave frequencies in deriving the high local oscillator signal.

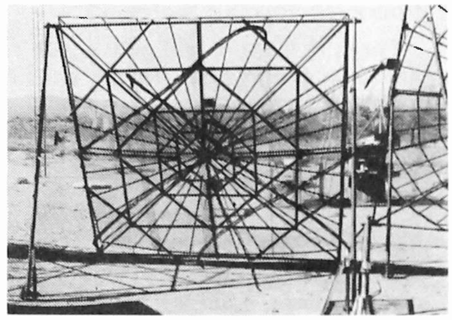
The Birkill Receiver approach, modified slightly, is shown in Fig. 3. As you can see, the LNA, the high-frequency local oscillator and mixer, plus a bulk gain stage operating in the 500-to-1,000 MHz region is mounted outside at the antenna. This simply means that what you feed "downstairs" to the remainder of the receiver, through coaxial cable, is (relatively speaking) low-frequency signals; in the 500-to-1,000 MHz region in this case. If the run is 100 feet or less, you can get by at these frequencies with RG-8 type coaxial cables whereas a similar run at 4 GHz requires ⅞-inch air-dielectric cable and special fittings.

Once indoors, the Birkill Receiver approach treats the signals contained in the 500-to-1,000 MHz IF bandwidth as a "group" and tunes them separately with a slightly modified (English, Mullard) UHF television tuner. The TVRO signals are 36 MHz wide (and of course still FM) and we need to convert them again (in frequency) down to a low enough IF where they can be detected. Experimenter Steve Birkill has found that an English Mullard type ELC1043/05 UHF TV tuner makes a dandy tunable second conversion system with only minor modifications. Unlike U.S. (of Canadian or Japanese, etc) UHF tuners designed for the American NTSC signals, the English (Mullard) tuner is capable of passing the full 36 MHz wide TVRO signal with only very minor modification. All American tuners checked have a 3 dB passband of not more than 10 to 11 MHz which simply means that they are not wide enough (even if modified) to handle the extra modulation/carrier width of the TVRO signal. Another advantage of the (European) UHF tuner, in this application, is that it has 20 dB of RF (500-1,000 MHz) gain and a quite respectable noise figure of under 5 dB. American market UHF tuners lack RF amplifier stages and consequently their front end noise figures are in the 12 dB and up region.

Birkill takes his low IF out at 35 MHz which allows him to use a Signetics 561 phase-locked-loop as a demodulator. Many of the commercial receivers also use phase-locked-loop demodulators, but Birkill's approach is unique since it allows the system user to change the effective bandwidth of the total system by varying the way the 561 is driven. This allows you to capture (that is, see) signals that are far weaker than would register on a standard 30- to 36-MHz wide IF satellite receiver; although admittedly the quality does suffer in the process. However, in his case, Steve Birkill has been able to produce very

continued on page 35

BUILD THIS



TEN FOOT SWAN SPHERICAL is almost opaque although aluminum screen mesh reflector surface is in place. Note Swan's use of squares and spokes to create sandwich layers that rigidly support antenna and reflective surface. Antenna tilt is handled by telescopic rear support rods with lower-ground-lip on hinges.

LOW COST BACKYARD SATELLITE TV EARTH STATION

Now you can build your own Satellite TV Earth Station in your own backyard for less than $999. This month we'll take a look at antenna design and how a spherical antenna can be built and erected.

ROBERT B. COOPER, JR.

IN THE AUGUST SEPTEMBER AND OCTOBER 1979 issues of **Radio-Electronics**, we discussed the evolution of the geostationary satellite service for North America and described the basics of its operation. In the January issue we looked at the hardware in the receive portion of the system and discussed the various approaches to hardware design. We are now ready, with this foundation, to begin the task of designing your first satellite television earth receiving terminal.

Design versus cost

If money is no object, you probably are more apt to buy a private satellite terminal than to build one (or portions of one). A list, current through the preparation of this article, of firms specializing on a national or regional basis in the sale of complete TVRO receiving systems (either 'turn-key installed' or on a hardware piece by piece basis) appears in Table 1. The bottom line is that you can purchase a first-rate commercial grade terminal for around $5,000 in hardware costs (and install it yourself) or have the job done for you with every wire in place and every nut and bolt secured for less than $10,000.

By building the terminal yourself, you are able to look carefully at the many design variations available and thus select the various module and sub-assembly approaches that best suit your own needs and talents. And in fact, because there are so many excellent designs around, we have already engaged in a bit of this selection process for you. We will lead you step-by-step through the various choices so that you will wind up with a complete terminal that best fits your needs.

Our approach is not to follow any single design philosophy. The *Howard Terminal* system, widely copied and very good in performance, may be a bit on the complicated side for a non-experienced builder. The *Coleman Terminal*, originally largely assembled from surplus (Bell-system discarded) microwave equipment, is in turn perhaps too much of a hit-and-miss proposition since the builder must locate many suddenly hard-to-find second hand microwave pieces to make it all play.

TABLE 1

Suppliers currently offering turnkey-installed home satellite receiving terminals and those who also offer hardware for do-it-yourself installations (*):

1. **Channel One, Inc.,** 68 Avalon, Newton, MA 02168
2. **HOMESAT, Inc.,** 3845 Pleasantdale Rd., Atlanta, GA 30340 (*)
3. **Gardiner Communications Corp.,** 1980 S. Post Oak Rd., Houston, TX 77056 (*)
4. **Microdyne-AFC,** 627 Lofstrand Lane, Rockville, MD 20850 (*)
5. **Satellite Television Systems,** Box 11249, Reno, NV 89510
6. **USTC,** P.O. Drawer 'S'. Afton, OK 74331
7. **Spacecoast Research,** Dept. B, Box 442, Altamonte Springs, FL 32701

The antenna portion is a similar case in point. Six months ago you had three choices; *locate* a surplus or used parabola, *buy* a new parabola, or, *build* a parabola. Many hundreds of people were turned onto satellite TV and then subsequently turned off because they couldn't locate a surplus parabola, didn't have the spare cash to purchase a new parabola, and felt unqualified to construct a homebrew one. Now, with the passage of time, a really low-cost, high-performance *non-parabolic* antenna has made its appearance, we shall shortly see.

Our design philosophy here will be to simply borrow the best technology that exists at this time from several different sources. We'll make you this promise. Over the next few issues of **Radio-Electronics**, you'll learn how to build your own complete terminal, including antenna, an ultra-low noise GaAs-FET LNA, and a twenty-four-channel frequency-agile receiver that ends up at VHF channel 3, 4 or 5 with a modulated NTSC RF output for under $1,000. You read right ... the whole, complete terminal, including antenna, for under $1,000.

Where do you put the gain?

There is passive and active gain required in the system. In the antenna portion (passive gain) the minimum gain required is a function of where your location falls on the satellite's EIRP pattern (see the September and October 1979 issues for a complete explanation). For discussion, we'll say you need at least 40 dB of passive gain in the system. That's a ten-foot minimum reflector surface any way you cut it. However, a 12-foot surface is even more desirable.

The decision on how much gain to design into the active portion (i.e., the LNA and the receiver) is more difficult to make. That's because we need signal gain for two reasons:

1. To amplify the 4 GHz signal voltage to a level where the demodulator can recover video (and audio) from the satellite signal, and,
2. To overcome (or override) the receiving system noise temperature.

Ideally, system noise temperature is set entirely by the low-noise capabilities of the first LNA stage(s). In the real world, the noise factor for the system is typically set by this *plus* the internal noise figure of the receiver stages. There are two types of 'noise' to be considered in the receiving system. Every amplifier stage (even a video amplifier) has a noise factor. However, when computing noise figure, it is often convenient to look at any device in the receiver that has 'loss' as a noise source as well. In this regard, a mixer stage (i.e., a stage that converts one incoming frequency to another outgoing frequency) has loss and therefore it contributes 'noise' to the overall system.

In modern receivers there are two approaches to getting the 4-GHz satellite input signal down to a low enough frequency where the modulation contained on the carrier can be demodulated to baseband. A single conversion receiver (i.e., the Coleman approach) takes you from 4 GHz to an IF of 70 MHz in a single conversion (or mixing) step. A double-conversion receiver gets you to 70 MHz from 4 GHz in two steps; the first typically takes you down into the 1.2-GHz region (although the selection of a high IF is entirely up to the receiver designer and could be any place from 500 MHz to 2,000 MHz) while the second mixes on down to the pretty much standard 70-MHz region.

The design approach we are going to follow here is the single-conversion option. However, this is offered with the understanding that in some ways the performance of a double-conversion receiver is superior to the single-con-

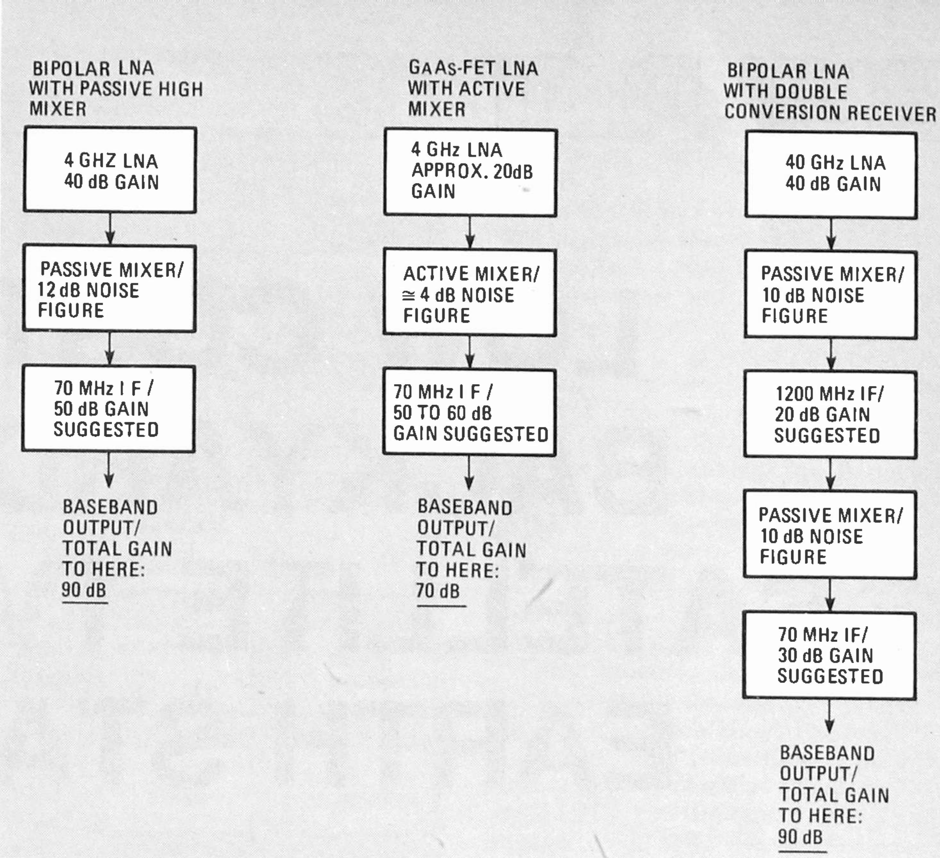


FIG. 1—GAIN REQUIREMENTS for three receiver approaches. Single-conversion receiver with bipolar LNA and passive mixer is shown in a. Single-conversion receiver with GaAs FET LNA and GaAs FET active mixer is shown in *b*. Double-conversion receiver with a bipolar LNA is shown in c.

version design set forth. In a double-conversion receiver, image rejection, stability and perhaps even selectivity can be better than in a single-conversion design. But, double-conversion techniques are more costly. They require that you have access to test equipment that you probably do not have available (adjusting and aligning a 1.2 GHz high IF does require some equipment not commonly available); and for home use, the trade offs seem to favor the single-conversion approach.

At the risk of oversimplifying the rationale for choosing a single-conversion approach, see Figure 1. Here we see that double conversion has a price tag attached to its 'perhaps' superior performance; you need more total system gain in order to make the double-conversion system perform properly. And gain not only costs money in parts and time, it also increases the complexity of the receiver.

Note in Fig. 1 that we are looking at:

1. A single-conversion receiver using a bipolar LNA and a totally passive mixer (left hand side); the gain required is 90 dB.
2. A double-conversion receiver using a bipolar LNA: the gain required is 90 dB (minimum).
3. A GaAs-FET LNA front end followed by a GaAs-FET active mixer that single-converts down to the 70 MHz IF: the gain required is 70 dB.

In all fairness, one could design a double-conversion receiver with an active GaAs-FET high mixer and this would in turn reduce the total gain requirements of the system since our 40 dB of LNA gain is largely predicted upon the noise-factor contribution of that first mixer stage (the one that gets us away from 4 GHz). However nobody has yet done this and as we are sticking with proven designs at this point the comparison of gain requirements remains valid for now.

What does all of this mean? Simply this. If you wish the system-noise temperature to be determined by the first LNA stage(s), and we do, we have to build enough total gain into the system at 4 GHz to insure that the noise contribution of that first mixer is overridden by the LNA stage(s) in front of it. By replacing the passive mixer (the mixer that gets us away from 4 GHz down to a lower IF) with an active mixer, we shift the noise contribution (i.e., mixing loss) of the first mixer out of the loss column and replace it with a gain or in the worse case a unity-gain device that makes no *significant* contribution to the system-noise factor. So where we previously required gobs of gain at 4 GHz to overcome the noise factor or mixing loss of the high (or only) mixer stage, we now require much more modest amounts of gain to establish our LNA first-stage noise figure as the primary noise factor in our electronic receiving system.

Electronic gain is least expensive to come by at the lowest frequency to be used in the RF portion (the 70 MHz IF) but unfortunately we cannot place all of the gain here. Some gain must go at 4 GHz as well. In Fig. 2 we see two options open to us.

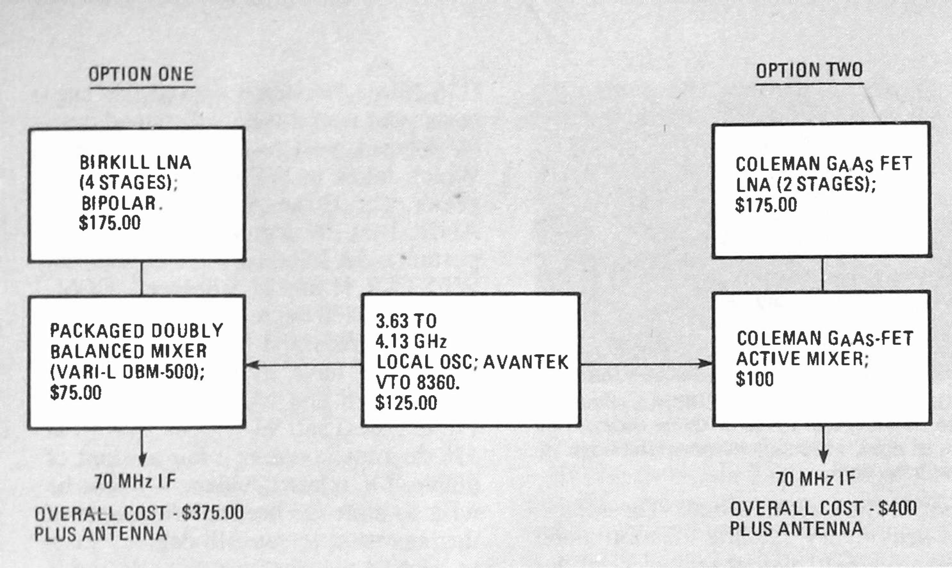


FIG. 2—TWO DESIGN APPROACHES to receiving satellite broadcasts. The Birkill approach is shown in *option 1* while the Coleman approach is shown in *option 2*.

1. As the balance of this article installment shall show, the most cost-effective approach to the antenna today is the *Swan Spherical TVRO* antenna. If you are not a particularly sharp trader or buyer you will still be hard pressed in most sections of the U.S.A. to spend more than $300 building this antenna.
2. In *option one* (Fig. 2) we could build a four-stage bipolar LNA (the so-called Birkill HXTR series LNA named after its developer Steve Birkill), follow this with a state-of-the-art doubly-balanced (passive) mixer such as the VARI-L DBM 500 4 GHz to 70 MHz (IF) package, and end up at 70 MHz with a total cost to that point of $675 including the antenna.
3. In *option two* (Fig. 2) we can build a two-stage Coleman GaAs-FET LNA and follow this with a single-stage Coleman GaAs-FET active mixer, again ending up at a 70 MHz IF for a total material cost of $700 including the antenna.

This would seem to suggest that the two approaches in getting 4 GHz energy out of the air and down to a manageable IF such as 70 MHz are very similar in cost. The truth is that the option-one approach has probably just about come to a resting place in costs (for the next year or so) while the GaAs-FET-approach is still largely dependent upon the $80 to $100 price tags on the GaAs-FET's themselves. With GaAs-FET prices starting to tumble, the cost of this approach may well be down another $100 or so before spring. That's one reason to seriously consider this approach. Another more compelling reason is that this approach uses far fewer devices overall; and as those Murphy Law believers know well, the more stuff you cram into a box, the more apt something is to go wrong when you can least afford the time or expense to fix it. Note that in both approaches we are using a newly available Avantek VTO 8360 oscillator module to provide the local-oscillator drive to our chosen mixer. We'll look more closely at the VTO 8360 in the next part of this series of articles.

Finally, in Fig. 3, we see how we are going to process the 70 MHz IF signal and what it is going to cost us. We have some gain stages at 70 MHz, a demodulator to extract the video modulation from the 70 MHz IF signal along with a few relatively simple baseband processing circuits, a demodulator to create audio from our 6.8 (or 6.2) MHz aural subcarrier, a VHF modulator to convert our baseband video and audio back to a NTSC compatible VHF TV channel (such as channel 3, 4 or 5) and a power-supply section which will provide operating voltages for the system. The total system cost (if you want to start budgeting your pennies now) is as follows:

1. Swan Spherical TVRO Antenna; $300 (or less)
2. 4 GHz front end to 70 MHz IF segment; $375 to $400
3. 70 MHz IF, baseband processing and VHF TV channel modulator with power supply; $250.

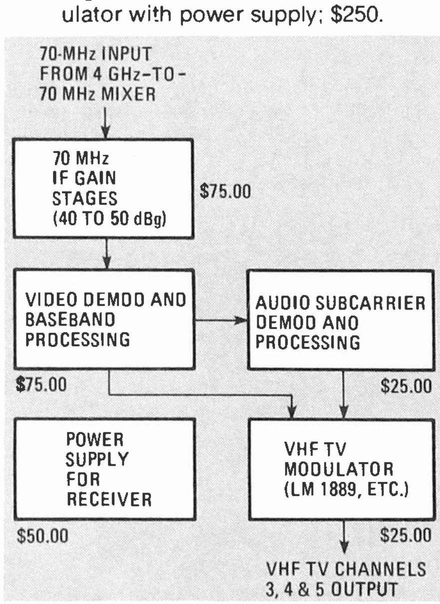


FIG. 3—METHOD AND COSTS of converting the 70-MHz IF to a VHF RF signal suitable for connecting to the antenna terminals of a TV receiver.

That brings us sufficiently in under $1,000 to allow you to indulge in some packaging of the system following a card cage approach if you wish and still have a little change left over for unexpected expenses.

Swan spherical TVRO antenna

There are several excellent reasons why the Swan TVRO antenna design is the best and most logical choice for the home builder:

1. **Materials**—Everything called for can be procured locally. Steel or aluminum pipe, tubing (round or square stock) plus aluminum window screening, and common hardware such as machine bolts, are all that is required for the reflector system. The feed-antenna is constructed from galvanized sheet metal.
2. **Cost**—$300 Give or take very little. Although, if you are a good shopper in metal yards you might shave as much as $100 from the total cost.
3. **Complexity**—Far less complex to create the 'spherical surface' design than to create a comparable parabolic surface. The principle is easy to grasp and uncomplicated to duplicate.

These factors alone should make the antenna very appealing. However there is a golden bonus with the spherical sections; the antenna is capable of 'looking at' many satellites at the same time. See Fig. 4.

The spherical antenna has such a gentle curve to its surface that it can "see" a 40 degree wide portion (or span) of the orbit belt effectively. The antenna is fixed, permanently, on the ground with the center pointed in a predetermined direction. We'll see how that works shortly. Every geostationary point-source in front of the antenna has a focus point out in front of the reflector surface. But this focus point changes for different angles of arrival. A satellite located directly on boresight will have its focal point directly in front of the center of the Spherical surface while a satellite west of the boresight point will focus slightly east of the center point. Conversely, satellites east of the boresight focus slightly west of the center point.

With this geometry, one moves the location of the focal- or feedpoint-antenna (left and right along a line parallel to the reflector surface) to switch from one satellite to another satellite. If you can leave the reflector stationary and move only the focal-point (or pickup) antenna, could you not actually install two or more pickup antennas so as to simultaneously receive two or more satellites? The answer is yes; something that cannot be done with a normal parabolic antenna.

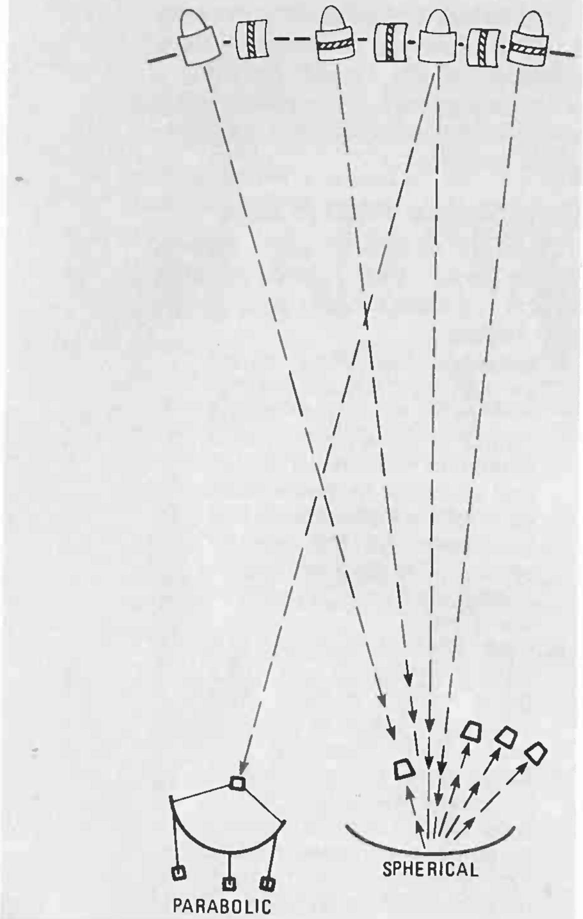


FIG. 4–PARABOLIC VERSUS SPHERICAL antennas. Normal parabolic dish antenna focuses all incoming energy onto a single focus point and as a result receives only one satellite at a time. To receive a different satellite the parabolic antenna must be redirected. The less radical curvature of a spherical antenna permits simultaneous reception of numerous satellites spread over up to 40 degrees of sky arc. Different satellites within the 40-degree arc can be received by moving the focus-point antenna or multiple satellites can be simultaneously received by using multiple focus point antennas.

How does it work?

Both the parabolic and the spherical reflector surfaces work on the same principle. The reflector surface is curved, in both dimensions. A 'cup' is formed and the center of the cup on a parabolic is directly in line with the satellite. All of the energy that is intercepted by the reflector surface is redirected towards a central focus-point. In a good efficiency parabolic antenna, approximately 55% of the total energy intercepted by the reflector surface ends up within the feed- or focal-point antenna.

But, the curve of the spherical antenna is very shallow; it is curved (or indented) sufficiently to cause the energy to focus but not so curved as to cause the RF energy to only focus when the reflector's center and the satellite are in-line together. In Fig. 4, we have a slightly exaggerated illustration of the primary difference between the parabolic (on the left) and the spherical reflector surfaces. The parabolic, because of its boresight requirement, 'sees' only a single satellite (or

FIG. 5–THREE SWAN SPHERICALS at the Bisbee, Arizona test range of Oliver Swan. From left to right, 14-footer, 10-footer and huge 19-footer on right.

spot in the sky) at a time. The spherical sees every satellite location along the orbit belt over a region ± 20 degrees from boresight (the center of the reflector straight ahead). Actually, the spherical surface can 'see' farther than that but the focal-point antenna has difficulty recovering wavefront energy offset from the boresight heading by more than 20 degrees. Look closely at Fig. 4; several separate feed-point antennas (the squared-off cups) are in place, each receiving energy from a separate satellite along the belt. Figure 5 shows three spherical antennas.

Aiming the antenna

If the spherical can see a 40-degree portion of the orbit belt, how do you decide where to center or 'boresight' the reflector surface? Most logically, you want the antenna to look (effectively) at as many satellites as possible. If one of those satellites is to be RCA's SATCOM FI (located now at 136 degrees west), it follows that since all other U.S. and Canadian satellites are east of that point, the 40-degree arc taken in by the spherical shall have as its most western point 136 degrees. That says that the boresight or center shall be 20 degrees less than 136 degrees (136-20) or 116 degrees. And this suggests your useful view will extend from 96 degrees west to 136 degrees west. Which takes in WESTAR I at 99 degrees, the three ANIKs (of which ANIK-B at 109 degrees is the most important), SATCOM FI at 119 degrees, WESTAR II at 123.5 degrees, COMSTAR I at 128 degrees, SATCOM FIII at 132 degrees and FI at 136 degrees. Since you have nothing between 96 (the eastern end when boresighted at 116 degrees) and 99 degrees, and FI at 136 degrees contains a fair amount of (cable TV related) video, it might be wise to shift the boresight a couple of degrees west to say 118 degrees so as to be sure that the important FI bird is well within the visible orbit belt for the antenna.

How do you do this? Drive a stake in the ground representing where you would like the center of the reflector to be. Use a surveyor's transit or quality compass and find *true* north. That's true north, *not* magnetic north; you'll have to correct for the difference in your area. The local airport control tower can tell you what your correction factor is. Drive a second stake so that the first one and the second one make a corrected-for-magnetic-north line that runs north and south.

Now take a transit or quality protractor and determine from your location a point in the sky that is over the equator 118 degrees west of Greenwich. Drive a third stake in line with the first stake and the line between stake 1 and 3 will be your boresight line. Left, or east (for northern hemisphere readers) 20 degrees and right (west) 20 degrees will be the extent of your orbit arc view with the Swan spherical antenna.

Now to create the spherical reflector surface. The photos here show how Oliver Swan, who developed the an-

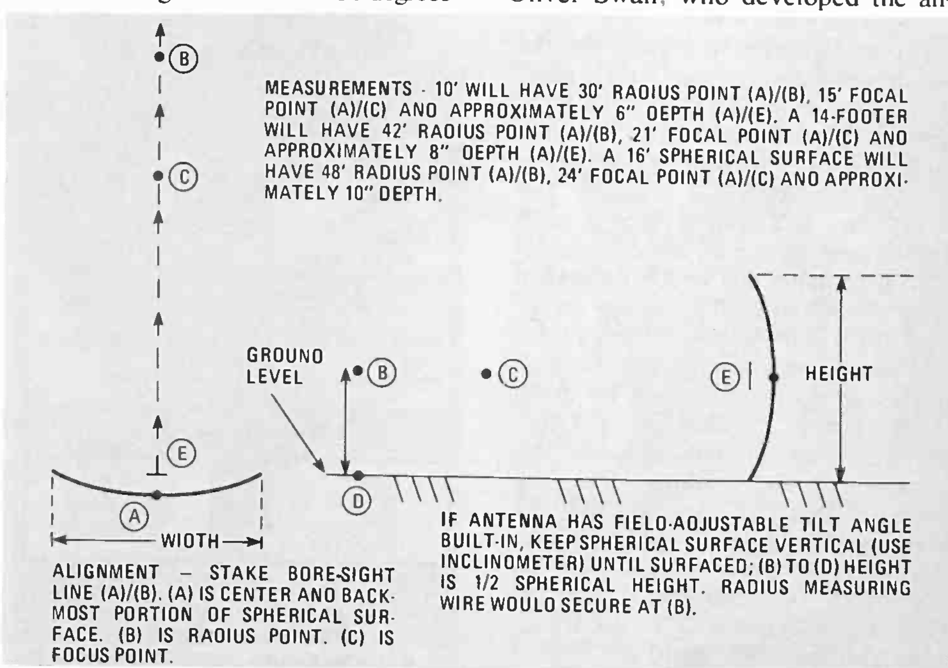


FIG. 6–DETERMINING RADIUS point and focal point of the spherical reflector surface. The spherical reflector surface is as high as it is wide.

tenna, has assembled them in the past. A detailed construction manual is available but an alert person can quickly see what is involved:

1. A ten-foot spherical antenna will have the gain of a 12-foot 55%-efficient parabolic antenna. A 14-foot spherical will have the gain of a 16-foot parabolic. A 16-foot spherical will operate like an 18-foot parabolic. (The height of the spherical surface is the same as the width. Therefore, when we speak of a 12-foot spherical surface, the surface is actually 12 feet high by 12 feet wide.)
2. All initial ground-staking measurements are made with three reference points; the center of the reflector-surface point (point A in Fig. 6), the radius point (point B in Fig. 6) and ultimately the focal point (point C in Fig. 6). The radius-point distance is three times the desired width or aperture of the spherical; a 30-foot radius for a 10-foot reflector surface. The focal point (which will become important after the reflector is completed) is 1.5 times the aperture (or 1/2 the radius point) and this is where your feed-horn pickup antenna will mount.

Having established the boresight line and the radius measurement point, create a system to measure within 1/16 of an inch from the radius point to any point on the reflector surface. The radius-point tie-down for the measur-

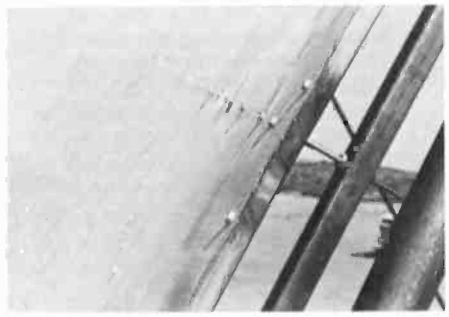


FIG. 7—SPHERICAL SHAPE is created by gently shaping the contour with 10×24 adjusting screws spread from center of reflector surface outward along spokes. Actual tweeking is done with a measuring device extended from radius point stretched taut to antenna surface.

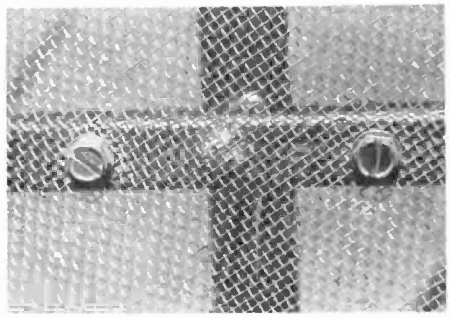


FIG. 8—SURFACE IS COVERED with aluminum window screen and tacked into place at 2- to 3-inch intervals with self-tapping metal screws.

ing wire/tape must be 50% of the height of the spherical reflector surface (if the width is 10 feet, the height will be 10 feet; which places the radius point tie-down 5 feet *above* ground, at a distance of 3 times the aperture of the antenna out along the boresight line).

To create the spherical curvature the framework for the reflector surface needs to be adjustable so that you can pull in the surface area to the 1/16-inch accuracy required using the radius point as a measurement tie-down. Swan's approach is shown here photographically; 2- and 4-inch 10:24 machine screws are simply adjustable jack screws that allow the outermost square tubing pieces to flex slightly to achieve the required curvature. See Fig. 7.

Surfacing of the spherical is handled with common aluminum window screening. Using 32- to 36-inch-wide material (it must be aluminum or metal to be reflective), the holes should be no more than 1/8th inch across to maximize the reflector surface efficiency and minimize RF signal leakage through the surface. Figure 8 shows how the screen is attached to the frame.

There are a few caveats concerning the construction of your own Swan spherical antenna:

1. Be accurate. The gain of the antenna is directly related to the care put into the surface accuracy. In turn, the surface accuracy (as measured from the radius point such that every point on the reflector's covered surface is within a ± 1/16th inch accuracy of all other points on the surface) is

ADDITIONAL SATELLITE DATA

Satellite television enthusiasts interested in learning more about the mechanics of satellite TV reception, and the wide variety of hardware and programming options available may find one or more of interest:

1. **Satellite Study Package**—Designed to gently lead you into the world of geostationary satellite communications; includes 72-page handbook that explains in lay terms the complete satellite TV story, shows how the system works, what services are available, lists dozens of sources for hardware and equipment. Plus - includes 22 × 35-inch four-color two-sided wall chart depicting all 30-plus TV carrying geostationary satellites, what each carries and how each operates. Order "Satellite Study Package" for $15 (first class mail shipment) in U.S. and Canada, $20 elsewhere (in U.S. funds) from: Satellite Television Technology, P.O. Box 2476, Napa, CA 94558.
2. **Satellite Terminal Construction Manuals**—Three separate manuals designed to help you build your own TVRO terminal. *Swan Spherical TVRO Antenna* manual completely describes the spherical TVRO antenna system with elaborate photos and drawings. *Howard Terminal* manual describes complete bipolar LNA system plus 24-channel frequency agile (tuneable) receiver using off the shelf parts and state-of-the-art technology. Very high quality receiver that can be duplicated (with bipolar LNA) for well under $1,000 in parts. *Coleman TD-2* manual describes starting off with surplus electronic equipment and building complete terminal for approximately $500; but, also includes Robert Coleman-designed GaAs-FET LNA stages, active GaAs-FET mixer and Avantek tuneable LO package. Manuals are priced at $30. each in U.S. and Canada, $35 each elsewhere (U.S. funds); or order all three manuals for package price of $80 from: Satellite Television Technology, P.O. Box G, Arcadia, OK 73007.
3. **Satellite Seminars**—A series of three-day seminars held periodically throughout the year at various U.S. locations; current *Satellite Private Terminal Seminar* (SPTS) is being held February 5, 6 and 7 in Miami, Florida. Conducted as a teaching seminar with course instructors, course guide books, manuals included, plus exhibits from satellite TV hardware manufacturers. Sessions are evenly divided between the technology of building low-cost terminals and business sessions designed to help people enter the field of marketing private terminals to homeowners. Next session after Miami is scheduled for San Francisco Bay Area of California in June. For information contact: SPTS '80, P.O. Box G, Arcadia, OK 73007 (405-396-2574).
4. **Satellite TV Monthly Publication**—A monthly magazine prepared in a newsletter format; *Coop's Satellite Digest* is edited and published by Bob Cooper. Mailed first class mail, covers the latest changes in satellite programming, satellite operations, and the technical progress of the low-cost receiving terminals. Subscription price is $50 per year in U.S. and Canada, $75 (in U.S. funds) elsewhere from: Coop's Satellite Digest, P.O. Box G, Arcadia, OK 73007. Sample copy for $5.00.

a result of the care you put into the supporting structure. The framework must be rigid, capable of taking wind (and, if applicable, ice) loads and advisably, easy to work with.

2. Be careful. No unsupported surface areas on the antenna should be larger than approximately 5 inches by 5 inches. Think of the surface as a gigantic patchwork quilt rather than a single reflector surface. Each patch is an area of some dimension and shape supported on three or four sides by tubular steel members on the backside. The total surface is the sum of all of the patches added together and the accuracy of the sum is the final result of how closely the *flat* (i.e. non-curved) surface of each patch is within the ± 1/16-inch accuracy required. So think out the support structure carefully and design it so that you have no patch areas larger than say 5 inches on a side.

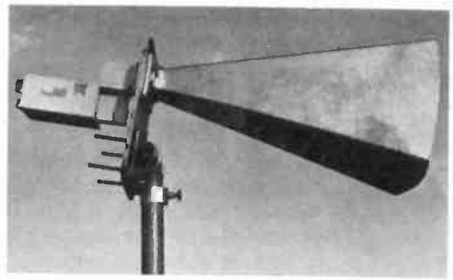


FIG. 11–DEEP-THROAT FEEDHORN (right) with commercial LNA (left). Feedhorn is constructed from galvanized steel, uses carefully welded seams following the pattern shown in Fig. 10. Flange at rear (narrow) end of feedhorn tapers to mate with WR-229 flange on input to LNA.

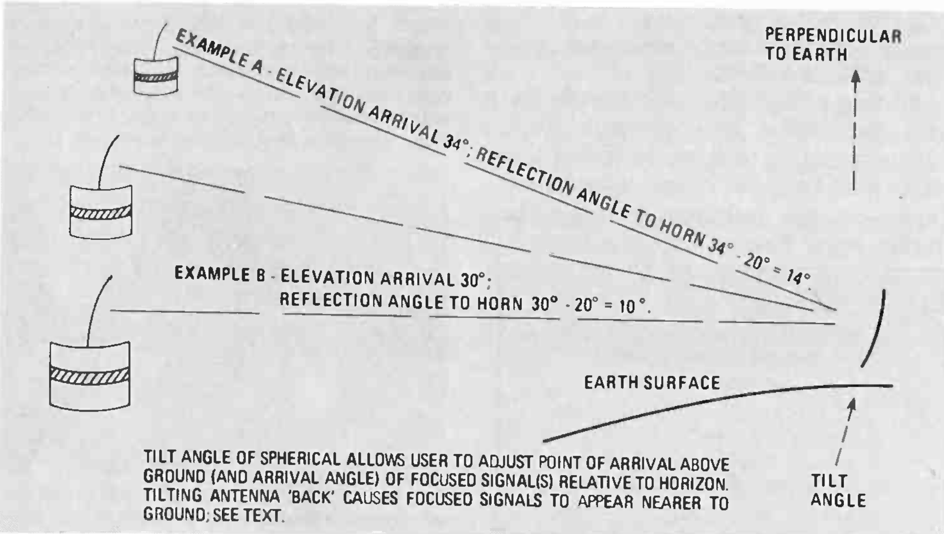


FIG. 9–TILTING THE SPHERICAL reflector surface back permits the user to adjust the angle of the reflected signals with respect to the ground.

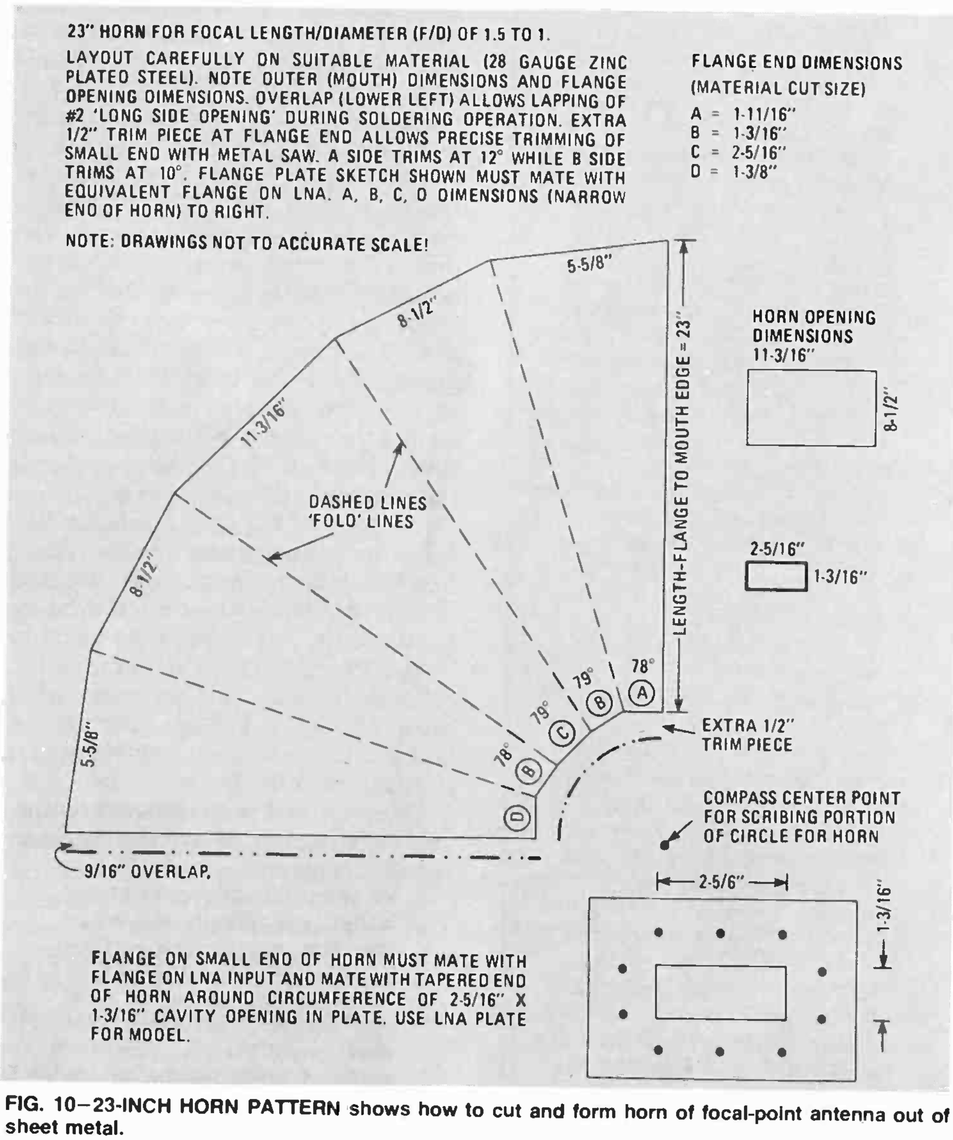


FIG. 10–23-INCH HORN PATTERN shows how to cut and form horn of focal-point antenna out of sheet metal.

The feed theory

The feedhorn is a very unusual design and there are proprietary rights of value here for the developer Oliver Swan. Suffice to say that the basic spherical antenna shown has phase *advance* (as in lead) while the feedhorn has phase delay. The advance of the reflector surface is self correcting with the delay of the special feedhorn as long as the incoming plane wavefront is within ± 20 degrees of the antenna's boresight. It is this phase relationship which falls apart beyond the 20-degrees-off-boresight point, destroying the effectiveness of the antenna system over off-boresight points beyond the 20 degree limits.

Keep in mind that the focus point varies for different azimuth angles of arrival. Remember that a signal from a satellite located dead-on the boresight path will be directly in front and in the middle of the antenna. But, signals from satellites stationed to the left or right of boresight will arrive at a focus point right and left (i.e., reversed) from the center boresight point.

There is also one other factor to be aware of in designing the antenna system; tilt angle. As shown in Fig. 9 the designer can decide just where he wants his signal above ground (i.e., how close to the ground or how high up) by changing the up-and-down angle of the reflector surface. For discussion, a reflector surface straight up and down is said to be perpendicular to the earth. In fact this is how you build and surface it regardless of the ultimate tilt angle that is to be used. After construction, on hinged pieces, the antenna is tilted back to the desired tilt angle for your location. A simple string and plumb-bob can be used to establish a vertical reference line and an inexpen-

continued on page 35

BACKYARD SATELLITE TV RECEIVER

Part 6: The front end is critical if you build your own satellite TV receiver. This issue we explore several different approaches to making one that will work.

ROBERT B. COOPER, JR.

LAST MONTH, THE BASIC DO-IT-YOURSELF satellite TV receiving system was described along with a novel spherical antenna system. This month, we'll look at several approaches to building the front end of the receiver.

Suitable LNA designs

The low-noise amplifier (LNA) decision depends largely on the mixing approach taken by the builder. As discussed last month, if you decide to use a prepackaged passive double-balanced mixer, such as the VARI-L DBM 500 unit, you will need more voltage gain from the LNA than if you elect to use an active GaAs-FET mixer. We'll show both LNA approaches here: the bipolar transistor system for use where 40 to 50 dB of gain is required, and the GaAs-FET transistor system where approximately half as much gain is needed.

A few comments are in order for those building microwave circuits for the first time. Read them carefully.

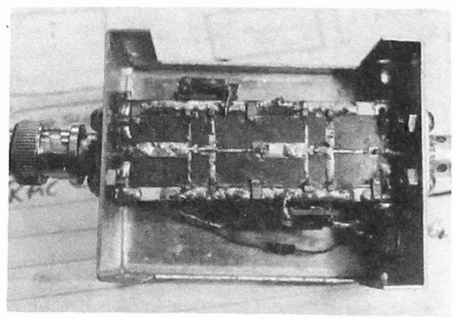
1. **Board material**—Normal circuit-board materials, such as the familiar G-10, are bad news at microwave frequencies. Any printed-circuit board *must* be designed for microwave applications. That means a microwave-rated Teflon dielectric board. Such board material is expensive but if you use very small amounts of it, the per-system costs will still be minimal.
2. **Double-sided**—Use only double-sided board for all circuits, including those at baseband frequencies. IC and packaged active devices used in this system, even when operating at baseband (video) frequencies, will oscillate when given the opportunity. (One recommended source for the microwave region board material that is used in the 4 GHz LNA stages and in the local oscillator/active mixer segments is the Rogers Corporation, Box 700, Chandler, AZ 85224. The board material is Duroid grade D-5880 226-127; dielectric thickness is 0.031 inches, 1 ounce clad on two sides.)
3. **Grounds**—All boards must be perimeter-grounded. That means all around, all four edges, both sides. Spot grounds through standup mounting lugs or pillars are not adequate.
4. **Lead length**—Exceedingly short, direct leads must be used with all parts. Remember that at microwave frequencies even a 1/8th-inch lead becomes an appreciable portion of a wavelength.
5. **Capacitors**—All capacitors specified in the microwave portion must be chip type. Normal ceramic, etc. capacitors have far too much inductance at microwave frequencies to be utilized. Where RF chokes are specified, put them in.

There are several sources for chip capacitors suitable for this project. One national source is Dielectric Labs, 69 Albany St., Cazenovia, N.Y. 13035. Smaller quantities can be obtained from Robert M. Coleman, RFD 3, Box 58-A Travelers Rest, SC 29690, and, from Satellite Innovations, Box 5673, Winston Salem, NC 27103. Where some of the circuits here specify certain brands of parts, such as capacitors, look to the *value* of the device and then locate a suitable substitute from the sources just given.

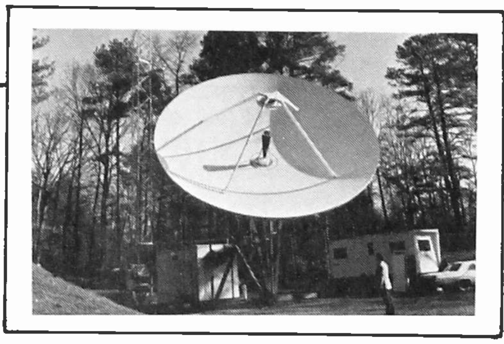
Two-stage bipolar LNA

The workhorse amplifier in this service is described in *Hewlett-Packard Applications Note 967:* a single-stage bipolar amplifier using either the HXTR-6102 or the HXTR-6101 devices. The 6102 is a better grade of the 6101 and it is capable of producing an LNA stage with approximately 10-11 dB of voltage gain in the 3.7 to 4.2 GHz range with a noise-temperature of between 270° and 290° Kelvin (K). The 6101 tends to be 15° to 25° K "hotter. (In this case, hotter is worse, not better!)

English experimenter Steve Birkill



TWO-STAGE BIPOLAR LNA is primarily an etched circuit board with very tiny parts mounted in precise position.



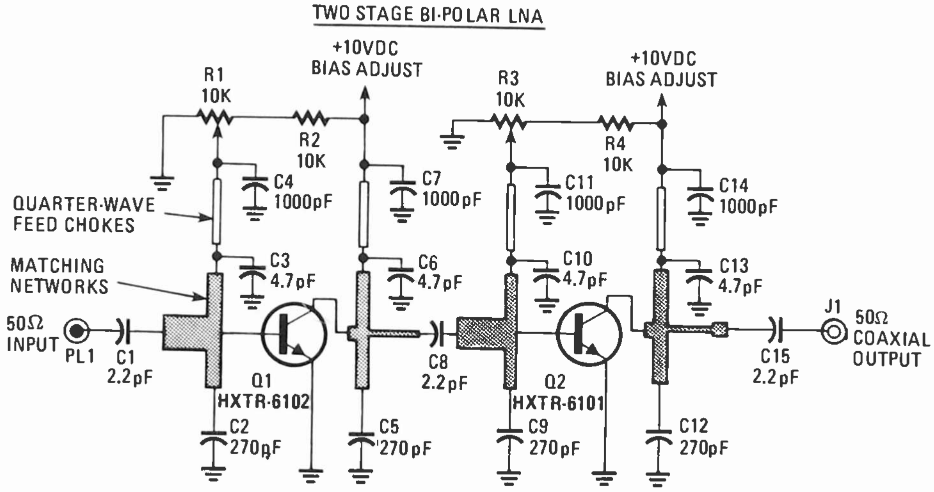


FIG. 1—SCHEMATIC DIAGRAM of the two-stage bipolar low-noise amplifier. The shaded areas represent leads and inductors that are vital parts of the circuit design.

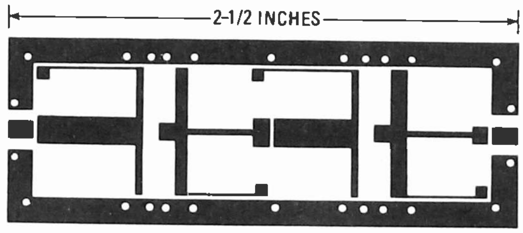


FIG. 2—PATTERN for etching the top surface of the LNA microstrip board. The lower surface is plain copper.

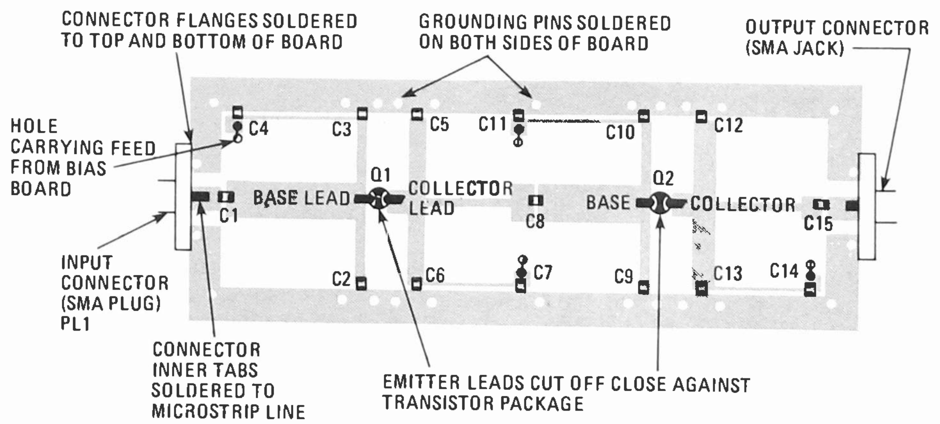


FIG. 3—COMPONENT LAYOUT shows placement of the transistors and capacitors. The capacitors are chip-type approximately 8 × 5 mm.

PARTS LIST

Two-stage bipolar LNA

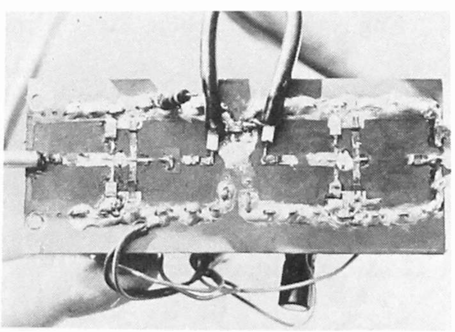
Q1—HXTR-6102 transistor (Hewlett-Packard)
Q2—HXTR-6101 transistor (Hewlett-Packard)
R1, R3—10,000 ohms, linear pot
R2, R4—10,000 ohms, ½ watt
C1, C8, C15—2.2 pF (Vitramon VJ0805A2R2DF)
C2, C5, C9, C12—270 pF (Vitramon VJ0805A271)
C3, C6, C10, C13—4.7 pF (Vitramon VJ0805A4R7DF)
C4, C7, C11, C14—1000 pF (Vitramon VJ0805X102KF)
PL1—SMA-type plug receptacle, tab contact, flush dielectric. Selectro type 50-646-4575-31 (gold plated) or similar
J1—SMA-type jack receptacle, tab contact, flush dielectric. Selectro 50-645-4575-31 (gold plated) or similar. Note: SMA connectors from different makers may be known variously as SMA, SRM, RIM or OSM.

Microstrip board: 62.5 × 22.5 × 0.79 mm. Duroid D-5880 226-127 dielectric constant 2.5, etched.

of Sheffield has developed a two-stage circuit board using this device series and it is shown in Fig. 1. A full-size circuit board is shown in Fig. 2. The opposite side of the board—which, as a reminder, *must* be a microwave-rated board—is solid copper.

Following the components selection guide given here and the construction tips, there is nothing to the system in the way of tuning or alignment. Ten VDC is the operating voltage; the base bias is adjusted with the 10K pots (one per stage) for a total device current of 4 mA. There is no tuning other than this; all resonant circuits are obtained with the etched inductances and the fixed capacitances shown.

Figure 3 shows a parts layout for the same two-stage amplifier. The bias parts (resistor plus pot per stage) can be located on the backside of the amplifier circuit board. When constructed, the board(s) must be mounted in a suitable microwave enclosure with suitable grounds all around as noted. The amplifier is very stable, but not when



TWO-STAGE HFET GaAs-FET LNA is similar in design and almost identical in layout to bipolar LNA two-stage device; primary difference being the substitution of HFET series transistors for bipolars.

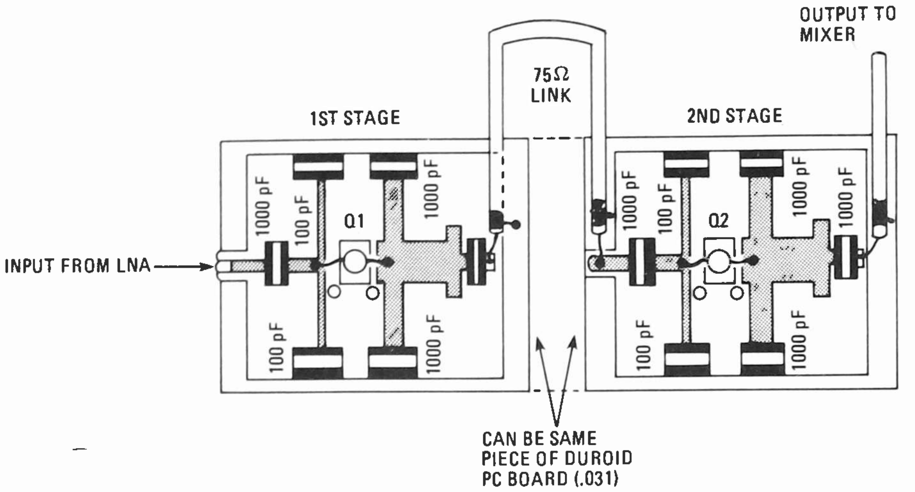
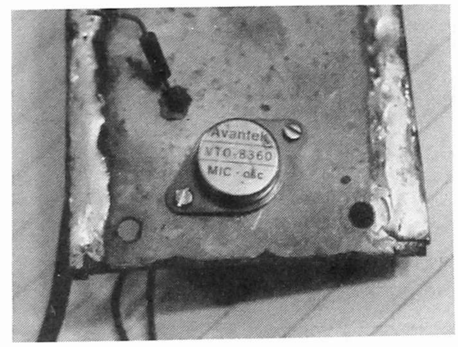


FIG. 4—SCHEMATIC AND LAYOUT of a two-stage LNA amplifier designed by Robert Coleman.


THIS INNOCENT-LOOKING DEVICE is capable of producing +10 dBm of local oscillator signal at 4 GHz! Avantek VTO 8360 is a microwave oscillator device totally self contained. It mounts on full-foil side of board with pins (leads) accessible on opposite board side with active 4-GHz circuits.

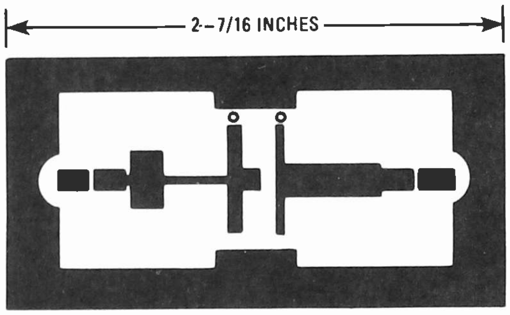


FIG. 5—PRINTED-CIRCUIT foil pattern for a single-stage low-noise amplifier. Two can be connected in cascade for more gain.

operating at the end of several clip leads as it dangles in space! One source for microwave enclosures is Adams Russell, Modpak Division, 80 Cambridge St., Burlington, MA 01803

Two-stage GaAs-FET LNA

If your approach is to follow the active mixer design of Robert Coleman, or you simply want a lower front-end noise figure than is possible with the HXTR bipolar series, then you can build the two-stage Coleman HFET-1101 amplifier. Figure 4 shows the parts layout for the HFET-1101 amplifier. The HFET series of GaAs-FET devices are also produced by Hewlett-Packard and a stocking distributor is Hallmark Electronics Corp., Attention: Paul Koeppen, 1208 Front St., Building K, Raleigh, NC 27609.

The HFET series of GaAs-FET's is capable of producing noise temperatures in the 170° K region (2-dB noise figure). Like the bipolar HXTR series, there is no tuning; the devices mount, turn on, and have voltage (positive and bias) supplies adjusted for optimum performance. Again, you cannot do that at the end of clip leads! The HFET data sheets suggest an operating voltage of +4.5 VDC. Developer Robert Coleman found that in the circuit shown (the actual-size foil pattern for a single stage is shown in Fig. 5.) the devices tended to be unstable at that voltage. By dropping the operating voltage to +3.6 and applying a −3.0 VDC (adjustable) bias to the gate lead (as shown in Fig. 6) he was able to make the stage

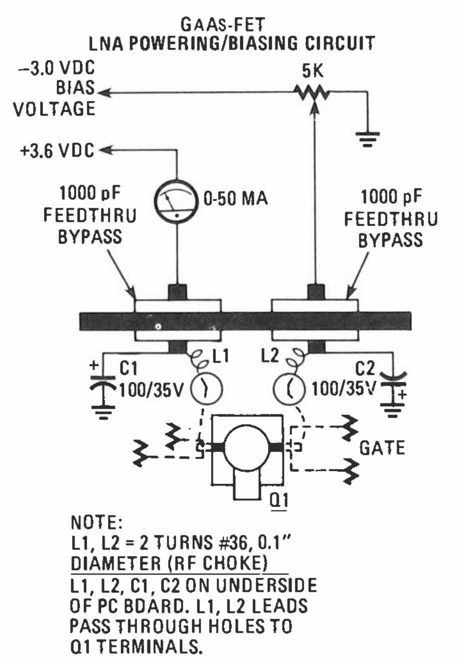


FIG. 6—HOW COLEMAN LNA IS BIASED AND POWERED. RF chokes L1 and L2 are mounted on underside of the board with leads anchored in holes in the PC board.

stable and optimize performance.

With all LNA stages (bipolar or GaAs-FET) there should be a separate bias control adjustment on *each* device. With the HFET devices, maximum gain occurs when the device current is around 40 mA *but* optimum noise figure occurs much lower; near 12 mA. Since in this situation voltage gain is secondary to noise-temperature performance, you will need a method of measuring the device current. Coleman's approach is to watch a current meter on the stage and keep an eye on the satellite-delivered picture to optimize the stages involved. Start with the first stage after setting both stages to approximately 12 mA current.

Circuit boards are available for either the Birkill bipolar (two-stage) amplifier or the single stage GaAs-FET device from Robert M. Coleman, RFD 3, Box 58-A, Travelers Rest, SC 29690. The price is $25 on the Birkill two-stage board and $15 on the single-stage GaAs-FET board. A parts list is not included for the GaAs-FET LNA since many of parts are already listed for the bipolar LNA. The 100pF capacitors are also made by Vitramon and Q1 and Q2 are Hewlett-Packard HFET-1101 transistors.

The VTO local oscillator

Creating a +10 dBm-level continuous-wave signal source for the local oscillator can be a bit of a pain, especially when the local oscillator must operate in the 4-GHz region! Fortunately, Avantek (3175 Bowers Avenue, Santa Clara, Ca. 95051) has solved that problem with a neatly packaged device that only requires board mounting (on microwave pc board). The device requires connection of a +15 VDC supply and application of a second +10-to-+20-VDC range tuning voltage. The VTO 8360 device is virtually a perfect local oscillator source for our applications since it tunes the range of interest and while not inexpensive (in the $125 region) it is far less costly to use than a lower-frequency oscillator chain with multiplying techniques. And, as Murphy notes, there is much less to go wrong because everything is inside on a substrate-designed package.

In Fig. 7 we have the complete local oscillator ready to drive any mixer put into service. The output pin four is linked through an appropriate *short* length of coaxial cable (if the length is under 6 inches, virtually any 50- or 75-ohm coax will function; but you will want to choose cable that will mate with the SMA or other series fittings you are using). Another approach is to

continued on page 35

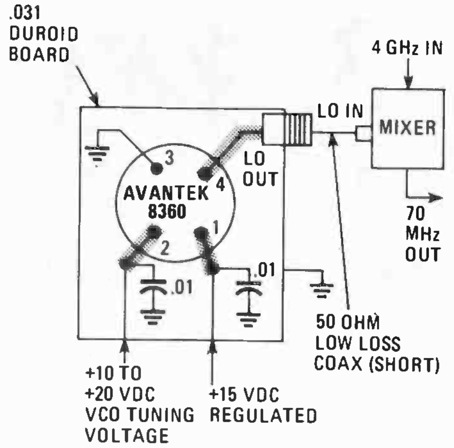


FIG. 7—THE AVANTEK VOLTAGE-CONTROLLED OSCILLATOR as it would be used as a local oscillator feeding a low-noise mixer.

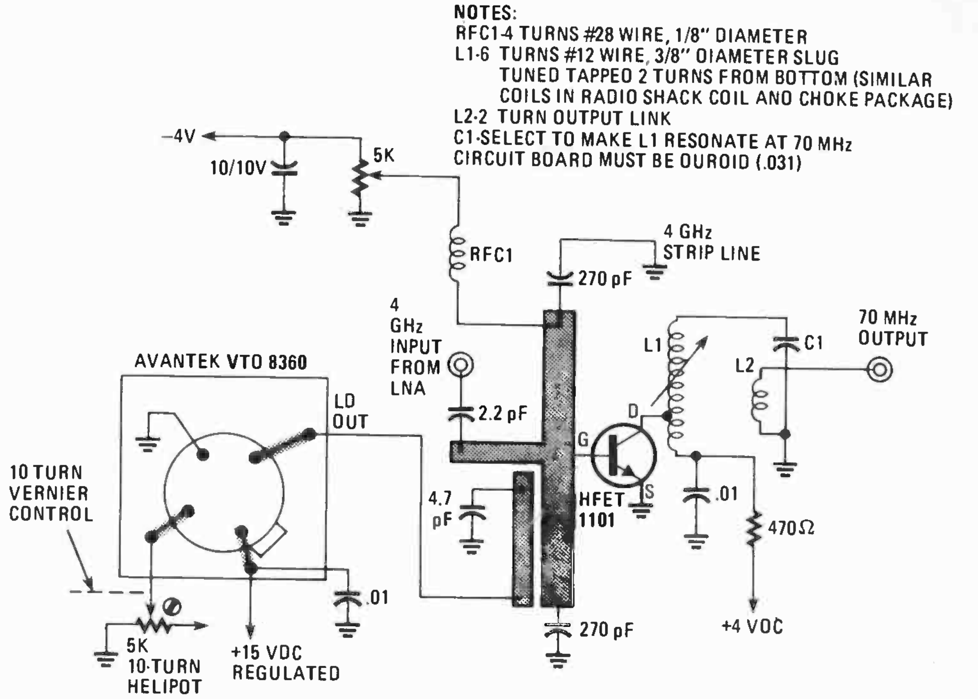


FIG. 8—A COMBINATION of the Avantek VCO and GaAs-FET used to make a tuneable 4 GHz-10 70-MHz converter using an active mixer.

use coaxial adapters to plug the output of the local oscillator directly into the appropriate input fitting on the mixer. If you are using the VARI-L DBM-500 mixer (VARI-L Company, Inc., 3883 Monaco Pkwy, Denver, CO 80297) you will need to build around the "standard" microwave SMA fittings. Note that just as you don't use any substantial lengths of low-frequency (i.e., RG-8, etc.) coaxial cable at 4 GHz, you also don't use fittings such as the UHF type. Even the BNC type are at best questionable in performance at 4 GHz, although there are some type N fittings "rated" to beyond 4 GHz. The proper fittings and coax (for short interconnecting runs) can be located at Satellite Innovations, P.O. Box 5673, Winston Salem, NC 27103). What you are looking for is type SMA series connectors and suitable coax to mate with the SMA series fittings.

There is absolutely nothing to do with the VTO 8360 local oscillator but mount it and turn it on. The +10-to-+20-VDC tuning voltage varies the operting frequency through the range of interest (3.630 to 4.130 GHz). Once again—make sure the VTO 8360 is mounted on microwave circuit board and is firmly seated into a housing before turning on.

Active Mixer

The most cost-effective approach to the 4-GHz front-end at the moment appears to be a marriage of two stages of GaAs-FET LNA to the active mixer (plus local oscillator) shown in Fig. 8. This is another Robert Coleman-developed circuit, using the HFET-1101 not as an amplifier but rather as a single-ended mixer. The 4-GHz energy from the LNA stage(s) is coupled into the gate of the HFET 1101. The 4-GHz range local oscillator signal from the VTO 8360 is coupled into the same gate through a coupling strip. The 4-GHz pair of signals mix in the GaAs-FET

Additional Satellite Material

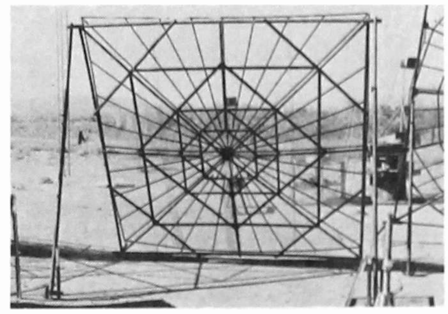
Satellite television reception enthusiasts interested in learning more about the fast developing satellite TV industry and the options available to persons building their own home terminals may find some of the following of interest:

1. **Satellite Study Package**—Designed to teach you how the satellite TV system operates, what the equipment requirements are, which services are available, and to whom and where. Includes a 72-page book written by Bob Cooper that explains in lay terms the complete satellite TV scene, plus a 22 × 35 inch four-color, two-sided wall chart depicting the location and operating characteristics of more than 30 geostationary satellites carrying television programming. Shipped via first class mail, price is $15 in U.S. and Canada (in U.S. funds), $20 elsewhere from: Satellite Television Technology, P.O. Box 2476, Napa, CA 94558.
2. **Coop's Satellite Digest**—A monthly publication providing up-to-date circuits, hardware, and satellite operational news. Mailed first class, widely read as the insider digest of the low-cost, private satellite TV industry. Price in U.S. and Canada is $50 per year ($75 outside, in U.S. funds);

   Order from: Coop's Satellite Digest, P.O. Box G, Arcadia, OK 73007.
3. **Paul Shuch Satellite Lecture Series Videotapes**—Approximately eight hours in Beta or VHS format; world-reknowned microwave teacher and satellite system engineer-designer H. Paul Shuch takes the student through the entire satellite equation from antenna to remodulated RF. Series originally videotaped at SPTS '79, world's first international seminar for low-cost satellite TV terminals. Excellent learning tool, teaching tool.

   Satellite Television Technology, P.O. Box G, Arcadia. OK 73007 (405-396-2574).
4. **SPTS '80/California**—A three-day lecture series and exhibit featuring noted satellite TV low-cost terminal-developers H. Taylor Howard of Stanford, Oliver Swan. who developed the Swan Spherical TVRO antenna, H. Paul Shuch of Microcomm, Robert Coleman of South Carolina, and many others. Combines classroom learning of the latest state of the art of satellite TV hardware, plus the latest in marketing of low-cost systems to private homes, with commercial exhibits of hardware. More than 25 sessions in three-day period with course learning materials. Next event will be held in San Francisco Bay Area in June of this year. For information, contact SPTS '80/California, P.O. Box G, Arcadia, OK 73007 (405-396-2574). Admission by pre-registration only, limited capacity.

BUILD THIS



BACKYARD SATELLITE TV RECEIVER

Conclusion of Bob Cooper's series on operational satellites that are relaying television programs and how we can receive their signals. This story describes receiver-system hardware and how it goes together.

ROBERT B. COOPER, JR.

IN THE PREVIOUS SIX PARTS OF THIS ARticle series, appearing in the August through October 1979 issues and the January through March 1980 issues, we have developed the background for the presently operational domestic and INTELSAT satellite systems that are transmitting television via satellite relay to virtually every portion of the globe. In the January and February issues, we have looked closely at the construction that is required to build your own low-cost home satellite television receiving terminal using a special spherical antenna design (February 1980 issue of **Radio-Electronics**), a single conversion 4-GHz-to-70-MHz GaAs-FET LNS plus active mixer package (March 1980 issue of **Radio-Electronics**) with an accompanying 24-channel frequency-agile tuning system.

In this seventh and final part, we will describe the 70-MHz IF-to-baseband system, and show you how to reconvert the baseband video and audio signals back to a standard NTSC-format RF carrier that can then be tuned in on your standard television receiver.

Gain at 70 MHz

In part six of this series we determined the amount of gain required between the 4-GHz feedhorn antenna receiving energy from the spherical reflector surface, and the baseband demodulator operating at 70 MHz. We determined that between 70 and 90 dB of voltage gain is required and that around 20 to 25 dB of that gain should be provided by the GaAs-FET LNA (two stages). The amplified signal from the LNA should then drive a similar GaAs-FET active mixer converting our 4-GHz signal down to a more manageable (and comfortable!) 70-MHz IF. The balance of the gain should then be provided by the 70-MHz circuitry.

Getting gain at 70 MHz is so simple that it almost becomes a waste of space here to tell you how to get it. Here are several suggestions:

1. You need 50 dB of gain here.
2. How you get it is relatively unimportant although if you can keep the noise figure of the IF amplifier at or below 8 dB you will be much better off. (Too high a noise figure here will degrade the carefully created low noise figure from the 4-GHz to 70-MHz mixer.)
3. You may *not* need to build this IF amplifier; it may be lying over in the corner of your shop or down the street.

Virtually all of the pre-1970 era microwave equipment employed a 70-MHz IF strip, usually made up of six to ten tubes operated in cascade or cascode. Typical IF strings have 50 to 90 dB of gain (much more than you need and you'll have to cut it back) and such gear is around in surplus outlets (usually without power supply) for around $10 an IF strip. Another source for 70-MHz IF gain is a CATV or MATV line amplifier. Typical line amps (the boards are available at local CATV firms, where they are taken out and discarded or sold as junk) have 25 to 30 dB of gain maximum and it will take a pair to get the gain you require.

However, the easiest—and perhaps for the most cheapest—way to get 50 or so dB of IF gain at 70 MHz is to investigate the Motorola AWT-120, a three-lead device that operates from near DC to around 300 MHz with 14 dB of gain with an acceptable noise figure. Four of those in series will give you 56 dB of voltage gain at 70 MHz. The AWT-120 is easy to make operate. Of the three leads, there is a ground pin, an input pin, and an output pin. The operating voltage (12 volts regulated) feeds into the output pin through a 330-ohm resistor. You couple into and out of the device through a .01 disc capacitor. Just pop four in a row on a piece of G-10 *double sided* board and you are in business. The AWT-120 costs around $6 per device; for $30 or so you have the full 50+ dB-gain IF strip.

Note however that our gain is spread from near DC to 300 MHz. And all we really want is the 30-MHz-wide spectrum between 55 MHz and 85MHz, centered on 70 MHz. Obviously we need some bandpass filtering in here someplace.

There are sound arguments for placing the 70-MHz bandpass filter *ahead* of the IF strip, and for placing it *after* the IF gain string. Some builders compromise and place it in the center of the string, or between the first and second AWT-120 devices. Briefly, if you place the bandpass filter ahead of the IF gain string, you run the risk of permitting a mistuned (or improperly built) 70-MHz bandpass filter to degrade the noise figure of the system. The bandpass filter will have some loss and that loss be-

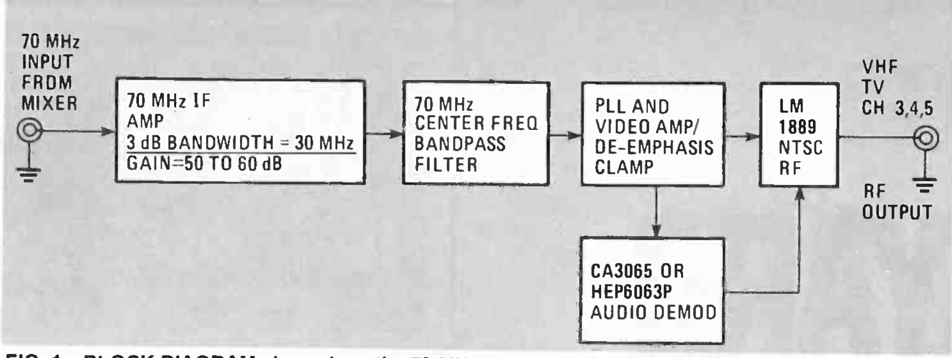


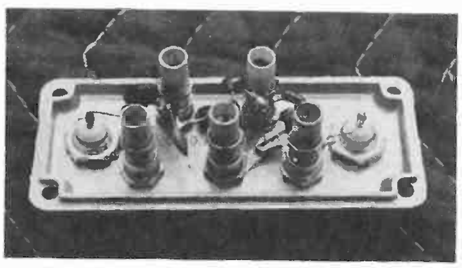
FIG. 1—BLOCK DIAGRAM shows how the 70-MHz signal from the mixer is converted to an NTSC RF output suitable for connection to the antenna terminals of your TV receiver.

comes part of the total system signal-to-noise equation. We'll describe a nearly foolproof 70-MHz bandpass filter for you shortly.

If you place the bandpass filter after the IF gain string, you run the risk of amplifying in the IF string undesirable heterodyne-produced products that may sum the desired signals coming out of the 4-GHz-to-70-MHz IF port on the mixer and causing the AWT-120 (or whatever) IF string to go into saturation. One solution is to run the AWT-120 first stage immediately after the 70-MHz IF output from the mixer, then stick in your bandpass filter, and proceed thereafter to amplify the 70-MHz signal in another three stages. We'll leave the final decision to you, noting only that we have placed the 70-MHz bandpass filter at the end of the IF string in the block diagram shown in Fig. 1.

Bandpass filter construction

There is no way we can suggest in good conscience that you will be able to construct and tune up this bandpass filter by eye or meter. You will need to run down a good CATV-type sweep generator and marker system to show you where in the spectrum you are tuning, and a detector and display. The sweep system should span the 50-to-100-MHz region as a minimum to align the bandpass filter properly.



70-MHZ IF BANDPASS FILTER is designed to pass a 30-MHz-wide spectrum centered on 70 MHz to provide the satellite-TV receiver with the selectivity required to separate adjacent satellite transponders.

Building the bandpass filter, shown in Figs. 2-a and 2-b, is not complicated, and if you follow the layout shown and mount the device in the Bud box recommended you won't have any problems. The coil forms, wire size, and capacitors (all are 5% dipped micas; don't substitute!) are important. If you change anything in the parts called for, you have just entered the R and D business and you'll have to recompensate other part valves accordingly. Properly constructed, and aligned, the passband of the IF filter will be from 55 to 85 MHz, ± 3 dB at the very edges, with less than 1.5-dB insertion loss and a passband ripple of less than ± 0.5 dB from 60 through 80 MHz.

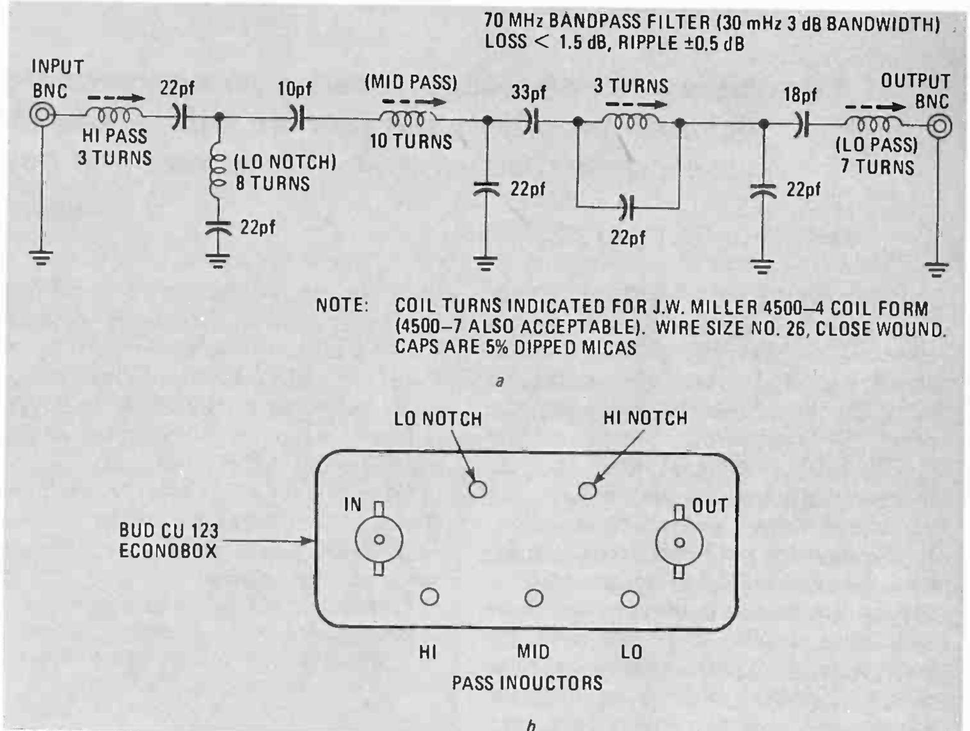


FIG. 2—70-MHZ BANDPASS FILTER is relatively easy to build and is housed in a standard Bud enclosure.

70 MHz to baseband

The utter simplicity of recovering good quality satellite TV video and audio becomes apparent as you study Fig. 3 (for the video) and Fig. 4 (for the audio). The secret is that you are coming into the field "late;" all of the dozen-transistor circuits worked out initially, some three or more years ago, have fallen by the wayside since clever design people such as Taylor Howard of Stanford tackled the project with an eye to reducing every section of the system to its basic required parts.

The 70-MHz IF input, following the 70-MHz IF gain-string, plugs into the input side (left hand side) of Fig. 3. The NE564 phase-locked loop makes a dandy video demodulator for this application, although note that there is this 5% warning:

The 564 is operating at the upper end

PARTS LIST (70 MHz to baseband, video/audio)

Resistors ¼ watt, 10% unless otherwise specified
R1—2200 ohms
R2—27,000 ohms
R3, R7; R27—1000 ohms
R4—200 ohms
R5, R17, R23, R28, R29—10,000 ohms
R6—3900 ohms
R8–R10, R12—147 ohms
R11—41 ohms
R13; R19—22,000 ohms
R14—470 ohms
R15, R16, R18—560 ohms
R20, R21—10,000 ohms, potentiometer
R22—270 ohms
R24–R26—100,000 ohms
R30—510 ohms
Capacitors
C1, C4, C6, C15, C19—.01 μF ceramic disc
C2—1 μF, 15 volts, electrolytic
C3—100 μF, 20 volts, electrolytic
C5—.001 μF ceramic disc
C7—1.5 to 8 pF trimmer
C8, C9—3 pF dipped silver mica
C10—330 pF
C11—4400 pF
C12—91 pF
C13—300 pF
C14—100 μF, 10 volts, electrolytic
C16—1 μF, 20 volts, electrolytic
C17—15 μF, 15 volts, electrolytic
C18—300 μF, 16 volts, electrolytic
C20—22 μF, 6 volts, electrolytic
IC1—7812 voltage regulator, +12 volts
IC2—NE564 phase-locked loop
IC3—NE592 video amplifier
Q1–Q3—2N2222
D1—HP5082/2800 Schottky diode (Hewlett-Packard)
D2—1N5248 Zener diode, 12 volts
RFC1—100 μH
RFC2—2.7 μH
RFC3—4.7 μH

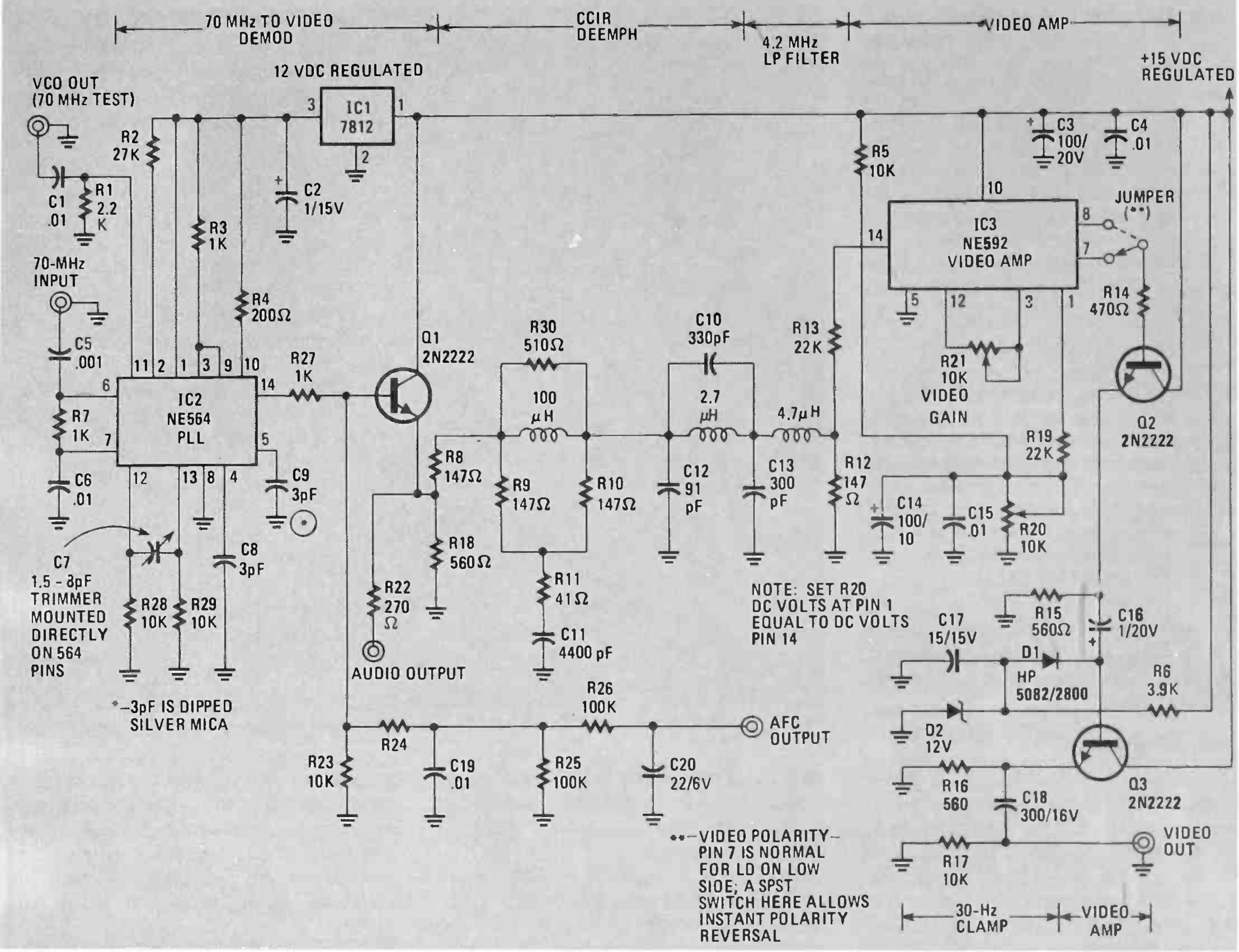


FIG. 3—BASEBAND VIDEO/AUDIO SYSTEM recovers video and audio signals from the 70-MHz output of the IF strip.

of its frequency range in this application, and you may find that some small percentage of the 564's around will not demodulate properly the video from the 70-MHz carrier. On the other hand (here's the good news), some 564's function to nearly 100 MHz. They are not touchy; several of the newer commercial receivers use the same device for this purpose and thousands of home-brewed receivers have been built using this approach.

The 564 provides video input that is amplified by a garden-variety 2N2222. Note that the audio-subcarrier comes off the emitter of the 2N2222 through a 270-ohm resistor. We'll talk about recovering the audio shortly.

Following the 2N2222 is a CCIR de-emphasis network. That's a collection of passive devices designed to establish the proper video baseband curve that matches the pre-emphasis networks used by the satellite TV transmitter on the uplink end. Without that network in place you'll get something less than true colors and will experience other video problems. Following the CCIR de-emphasis network is a 4.2-MHz low-pass filter network. This is in place to insure that the 6.2-, 6.8,- or 7.4-MHz audio subcarrier does not get on into the balance of the video circuits. Frequencies above 4.2 MHz in the baseband region do not contribute to the video quality and in fact, if left in, will create high-frequency video noise on your baseband video signal.

Between the second 2N2222 (following the NE592) and the third such stage is a harmless-looking Schottky diode-the HP 5082/2800. That is a clamp diode. You may recall from previous sections that the uplink signals transmitted to the satellites are "frequency dithered" at a 30-Hz rate as a means of dispersing the energy waveform over a relatively wide band (36 MHz if you follow out to the 1% energy levels). That dispersal action was motivated by designers of early INTELSAT systems, who feared they might cause interference to terrestrial microwave circuits operating in the same 3.7-to-4.2-GHz region. Spreading the waveform energy out with the 30-Hz waveform reduces the probability that any appreciable amount of satellite TV downlink energy will get into any terrestrial system. To get rid of the 30-Hz waveform we shove the video into a hard clamp. The Schottky diode is fast and it clamps the 30-Hz waveform to ground by as much as 40 dB or more. That either eliminates the 30-Hz flicker in the picture or reduces it to the point where it cannot be seen.

There are these caveats and cautions about this portion of the system:

1. Use only double-sided board; good quality G-10 board will do.
2. Mount the finished board in a container, grounding all the way around on both sides of the board. Place the 15 VDC regulated line on the backside of the board along with power supply bypasses and the 7812 regulator.
3. The 70-MHz VCO output test jack is for setting the operating frequency of the PLL to 70 MHz. Adjust the 1.5-to-8 pF trimmer (C7) for 70 MHz (a counter is handy but you could do it with the TV monitor tuning for best picture).
4. Adjust pot R20 off pin 1 of the NE592 for the same voltage on pin 1 as you have on pin 14 of the same device.
5. The AFC output shown is not totally applicable to the system you are *presently* building. As you get more sophisticated in using your home terminal you may wish to add an AFC system later on (as many have) and that brings it out so it is available when you wish to add the feature.

6. The output of the NE592 (pins 7 or 8) is selectable for good reason. As long as your local oscillator is driving the 4-GHz-to-70-MHz mixer on the low side (i.e. 4 GHz input frequency minus the VTO-8360 local-oscillator source equals 70 MHz) you will find the video in the proper polarity on pin 8. If you mistune and end up with the local oscillator on the high-frequency side, you'll have to swap the video output lead to pin 7 to re-establish the proper video polarity. A simple switch here will make changing simple.
7. The purpose of 10K video-gain pot between pins 12 and 3 on the NE592 is to set your video output level into your NTSC format RF modulator. Simply tune it for best looking picture, through the modulator, on your standard TV set (typically in the 1 volt peak-to-peak region if you can look at the level on a scope.)

There is absolutely nothing else to adjust or fiddle with! You have just gone from 70 MHz to relatively complicated FM video to baseband with a minimum of harrassment.

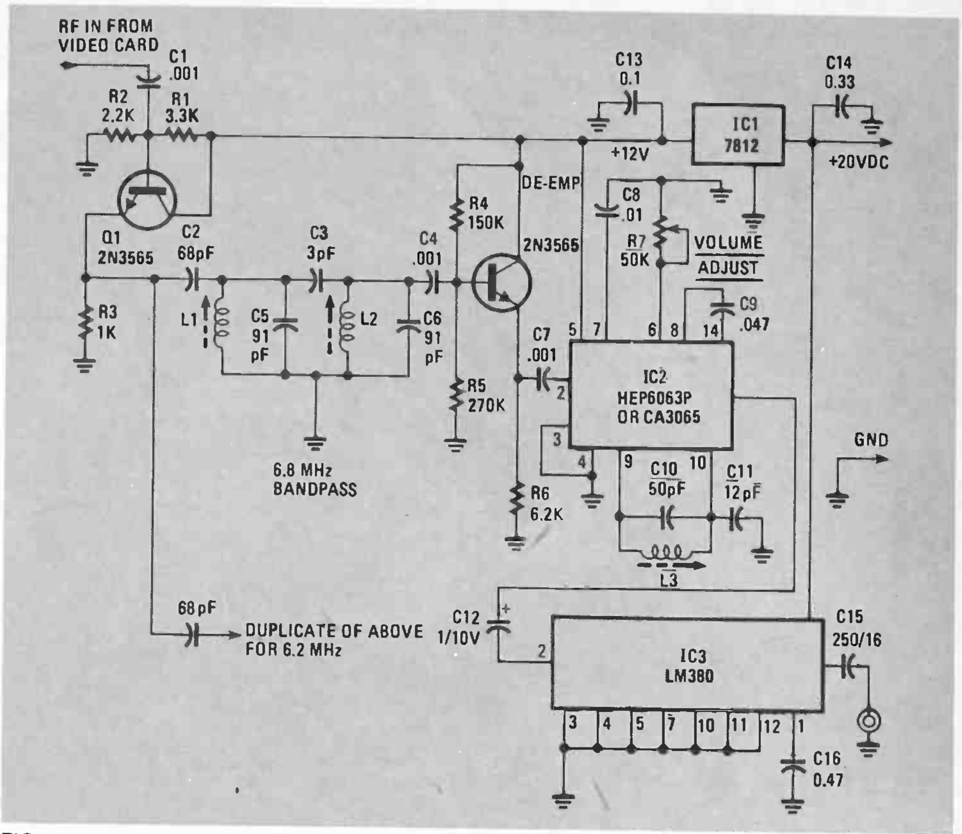


FIG. 4—6.8-MHZ AUDIO DEMODULATOR. Circuit is duplicated for recovering 6.2-MHz audio signal.

Recovering Audio

The RCA SATCOM and Western Union WESTAR birds carry their FM audio on either 6.2 or the more common 6.8-MHz subcarriers. When you demodulate the 70-MHz IF signal, the NE564 PLL recovers that higher-frequency baseband component right along with the video. We take it off after the first 2N2222 baseband amplifier and send it on to a second demodulator which is L-C tuned to the 6.2- or 6.8-MHz subcarrier frequency.

Two methods of recovering the audio are presented here. In Fig. 4 we have the basic (Taylor Howard developed) audio demodulator that uses a 2N3565 amplifier, a tuned network designed for either 6.8- or 6.2-MHz, a second 2N3565 amplifier, a (Motorola) HEP6063P demodulator (or RCA CA3065), and finally an audio amplifier. That system has seen thousands of duplications by home builders and it works just fine.

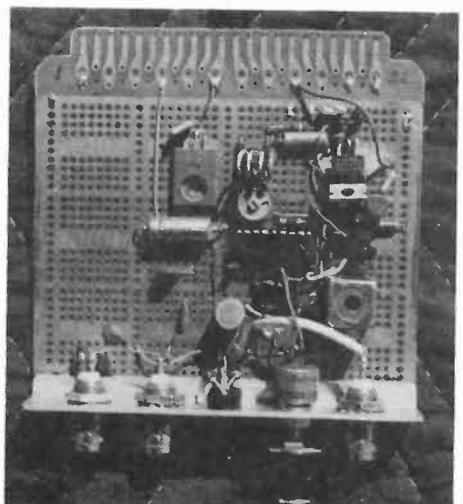
Simply tune L1 and L2 for the desired frequency (6.8- or 6.2-MHz) and then tune L3 for recovery of the audio on that frequency by simply listening on some suitable audio-display system. There is a 50K volume-control pot and those are the only adjustments that are in the system.

Figure 5 shows how to do the same thing for about $12 for each audio subcarrier desired and perhaps 15 minutes of your time. Several satellite TV enthusiasts in the Indianapolis area, where RCA has a production facility, discovered that the RCA XL-100 audio demodulator (model PM-200) can be field-modified with a pair of capacitors to tune not the usual 4.5-MHz subcarrier channel found in the NTSC system but rather the 6.2- or 6.8-MHz subcarrier found in the satellite system. The PM-200 is a stock replacement item for XL-100 chassis; it is a complete module ready to hook up and operate (RCA's stock number is 130-753). You go into the module and add capacitors C1 and C2 (both 33 pF to hit 6.8-MHz) as shown. Input is through pin 3. As noted, the cost of this module (new, through an RCA parts house) is in the $12 range.

Once again, recovering the satellite audio is not much of a trick.

Modulating to NTSC

Now that you have the baseband video and audio displayed on a color-video monitor and audio system, it would be nice to watch your favorite programming from satellite programs on your TV receiver. In fact, if you are like most of us, you don't own a video monitor in the first place. So let's get the baseband signal back to NTSC format RF.



RF MODULATOR construction followed by do-it-yourself satellite-TV enthusiasts. This module is the RF modulator described in the text using the LM1889 IC device.

PARTS LIST
(Audio demodulator, Fig. 4)

Resistors ¼ watt, 10% unless otherwise noted
R1—3300 ohms
R2—2200 ohms
R3—1000 ohms
R4—150,000 ohms
R5—270,000 ohms
R6—6200 ohms
R7—50,000 ohms potentiometer
Capacitors
C1, C4, C7—.001 μF
C2—68 pF dipped mica
C3—3 pF dipped mica
C5, C6—91 pF dipped mica
C8—.01 μF
C9—.047 μF
C10—50 pF dipped mica
C11—12 pF dipped mica
C12—1 μF 10 volts, electrolytic
C13—0.1 μF
C14—.33 μF
C15—250 μF, 16 volts, electrolytic
C16—.47 μF
Q1, Q2—2N3565
IC1—7812 voltage regulator, +12 volts
IC2*—HEP6063P or CA3065
IC3*—LM380
L1, L2—adjustable RF coil, 3—7 μH (J.W. Miller No. 9051)
L3—adjustable RF coil, 7—14 μH (J.W. Miller No. 9052)
*Note: The RCA CA3134GM can replace the CA3065/LM380 combination

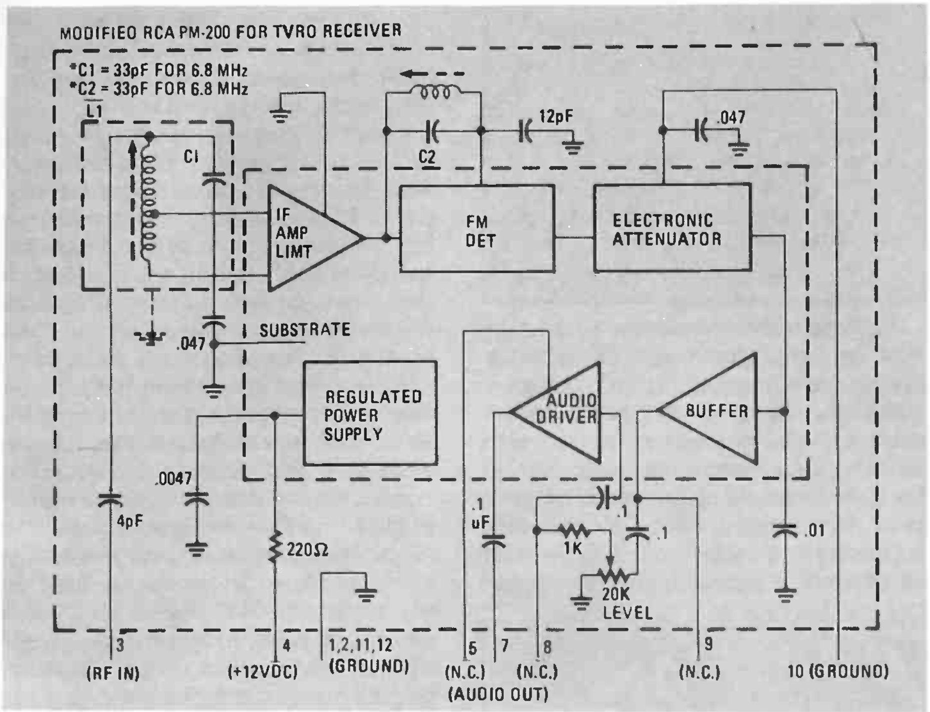


FIG. 5—ALTERNATE APPROACH to subcarrier audio detection uses a standard module from an RC TV receiver.

If you own a video-tape recorder, you already have a modulator. Simply connect the video output of the satellite receiver to the video input jack on the VCR, the AUDIO OUT to the AUDIO IN. and switch the VCR to CAMERA INPUT.

Now run a piece of RG-59/U coaxial cable from the output of the VCR to your TV receiver(s). And the satellite signals will appear on the modulated channel determined by the VCR modulator switch (typically Channel 3 or 4).

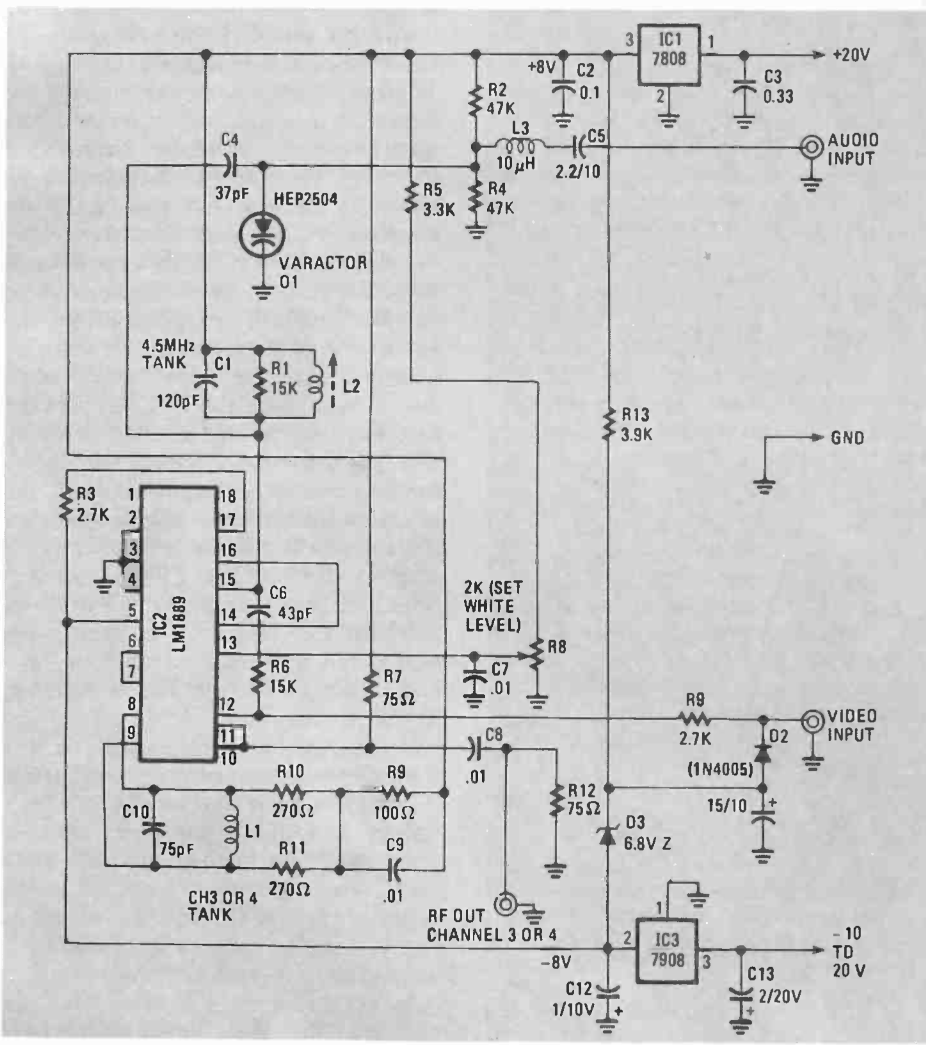


FIG. 6—NTSC RF MODULATOR for Channel 3, 4, or 5.

If you don't have a VCR, you'll need to build, or buy, your own video RF modulator. The most common RF modulator used by satellite TV enthusiasts is shown in Fig. 6. This system uses the LM1889 IC that is really a miniature TV transmitter disguised as an IC. The LM1889 device (or something very similar) is found in dozens of TV games, VCR modulators, computer modulators, and so on. The 1889 is available from firms such as Poly-Pak, usually for under $5.00. A complete modulator kit, using the LM1889 is available (model PXP-4500) for around $25 (ATV Research, 13-B Boardway, Dakota City, NB 68731).

The schematic in Fig. 6 shows what is involved. Coil L2 establishes the 4.5-MHz sub-carrier for the audio in a tuned network and a 2K pot connected to pin two of the 1889 establishes the saturated white level for the video. Although the schematic establishes tuning procedures (off pins 8 and 9 of the 1889) for Channel 3 or 4, many people have also found that the system will function on VHF TV Channel 5 as well, by adjusting the tank circuit accordingly.

A modulator such as this is capable of putting out around 10,000 microvolts of maxium signal (3,000 is more typical). That is more than enough RF voltage to drive through several hundred feet of RG-59/U coaxial cable into, perhaps, as many as a half dozen TV receivers con-

PARTS LIST (RF-modulator, Fig. 6)

Resistors ¼-watt, 10% unless otherwise specified.

R1, R6—15,000 ohms
R2, R4—47,000 ohms
R3, R9—2700 ohms
R5—3300 ohms
R7, R12—75 ohms
R8—2000 ohms potentiometer
R9—100 ohms
R10, R11—270 ohms
R13—3000 ohms

Capacitors

C1—120 pF dipped mica
C2—0.1 μF ceramic disc
C3—.33 μF ceramic disc
C4—37 pF dipped mica
C5—2.2 μF, 10 volts, electrolytic
C6—43 pF dipped mica
C7—C9—.01μF ceramic disc
C10—75 pF dipped mica
C11—15 μF, 10 volts, electrolytic
C12—1 μF, 10 volts, electroytic
C13—20 μF, 20 volts, electrolytic
IC1—7808 voltage regulator, +8 volts
IC2—LM1889 TV video modulator
IC3—7908 voltage regulator, −8 volts
D1—HEP2504 varactor diode (Motorola)
D2—1N4005 diode
D3—Zener diode, 6.3 volts
L1—tank coil, .08μH (3 turns No. 16 wire air-wound ¼" ID, ⅜" long)
L2—adjustable RF coil, 7—14 μH (J. W. Miller type 9052)
L3—10 μH molded RF choke

nected to the system through appropriate 75-ohm splitters and taps.

Power supply

There is little to be said about the system powering that is not obvious in the schematics. The total power drain will be in the ½-ampere range at the master supply level of 20 volts. Regulation, where noted, is very important. Pure DC, well filtered, is very important. Protection of the satellite TV receiver, from line glitches is also very important. If you live in an area where you have erratic AC line service, invest a few dollars in some fast-acting devices so that AC line spikes and surges don't eat up your relatively delicate 4-GHz parts. Saving $10 on the master power supply may cost you a $100 GAAS-FET, so use a good, stiff, regulated supply.

SATELLITE TV COLUMN

To keep you abreast of the latest happenings in this exciting new field, a monthly column entitled "Satellite TV News" will appear in **Radio-Electronics.** This column will keep you informed of the latest technological developments, equipment designs, and satellite broadcasts.

Satellite television has been called the new frontier of electronics. There is little doubt that a proliferation of communication satellites in the geostationary orbit will change the way we perceive ourselves and our world neighbors in the decade ahead. Heretofore we have been able to keep control of our individual nationalistic goals through a flood of programming created largely by our own countrymen. What we have seen of Brazil, for example, or Zambia, have been the views of our own program producers, writers, and actors.

Satellite television is changing all of that: a trickle now, a flood within the next ten years. International satellites (INTELSAT) already in operation are beaming programs from Brazil, Zambia, and dozens of other nations not only to their own citizens but to 40% of the whole globe at a time. Regional satellites with shaped antenna patterns are spilling the programs from India, for example, throughout Africa and the Middle East. A Russian geostationary satellite system called Statsionar is nearing completion so that by 1981 you may sit in your home—virtually any place in North America—and tune in Moscow directly. Those Statsionar satellites can be expected, like Radio Moscow of shortwave fame, to become instruments of their operators, beaming video propaganda over the entire globe.

Satellite receiving hardware is a new, business still struggling between the first $50,000 INTELSAT receivers and what will become ultimately (perhaps soon) $1,000 receivers sold through electronic emporiums. By 1990, satellite television will be a household word and $250 receiving *systems* will proliferate into every book corner of the world.

Just as our U.S. television system has shaped and re-shaped the America of the 1940's into the present-day America, so, too, will satellite television shape and re-shape the world of the early 1980's into an entirely different world by the year 2,000; some say perhaps ten years sooner than that.

Until October of 1979, for private individuals to own satellite television receivers here in the United States was something of a misdemeanor. It wasn't clearly illegal, but wasn't approved by law either. Since the FCC decided last October that private satellite terminals did not require a federal license, a marked change has begun in the attitude of electronic hardware suppliers throughout the world. Suddenly there *is* a marketplace for satellite TV gear—a very large, national and even worldwide marketplace. That FCC decision alone will result in dozens of receiving-system packages entering the marketplace in the year ahead.

As an electronics enthusiast you have a leg up on the rest of your countrymen. You have a head start on this new technology and, for a few years at least, your expertise in that area will make you a special person with special knowledge—and the opportunity either to enjoy it to the fullest, or cash in on a very attractive business opportunity.

Never before in electronics has the sky been the limit. Never before have we had satellite television available. R-E

LEARNING MORE ABOUT SATELLITE TV

If you are fascinated by the rapid development of satellite television as a worldwide video communications system, some of the following reference materials may be of interest to you:

Satellite Study Package—A thorough study of how the satellite system works, what the individual elements of a successful satellite TV receiving system are, how they work, and what they do. Includes a 72-page book written by Bob Cooper that explains in lay terms just what the satellite TV revolution is all about. Includes reference section with dozens of other study materials sourced. Also includes 22 × 35-inch four-color, two-sided wall chart depicting the presently operating international network of geostationary communication satellites, where they are, and what their operational parameters are. Price is $15 for first class mail delivery in U.S. and Canada, $20 (in U.S. funds) elsewhere from: Satellite Television Technology, P.O. Box 2476 Napa, CA 94558.

Satellite Seminar—The third in a series of *Satellite Private Terminal Seminars;* scheduled for mid-June in the San Francisco Bay Area of California. Three days of lectures; classroom instruction taught by leading designers of low-cost satellite TV systems. A combination of "how to do it yourself" featuring the latest state-of-the-art technology and "entering the satellite TV business" sessions. Two early seminars (Oklahoma in August, 1979. Miami, Florida this past February) were total sell outs, so advance registration is a must. For complete details contact: SPTS '80/California, P.O. Box G. Arcadia, Oklahoma 73007.

Construction Manuals—A series of three manuals describing the construction of (1) the *Swan spherical TVRO* multi-satellite antenna, (2) *Coleman TD-2 conversion Satellite TV Terminal*, and (3) *Howard Terminal Receiver*. Swan's manual takes you into the satellite TV antenna world for less than $300-cost for a very effective 10 × 10 foot antenna that features the unique ability to receive up to 9 separate satellites with one antenna in a fixed position. The *Coleman TD-2* manual covers conversion of surplus (inexpensive) microwave equipment to satellite TV reception, plus illustrates new low-cost microwave technology for home builders. The *Howard Terminal Receiver* manual describes 24-channel frequency-agile, double conversion receiver, LNA and feed antenna system that can be duplicated for under $800. Price per manual is $30, all three for $80 (U.S. funds) from Satellite Television Technology, P.O. Box G, Arcadia, Ok. 73007.

Monthly Publication—A "nuts and bolts" monthly publication aimed squarely at explaining the construction of low-cost terminals, satellite operations, and the business of selling and installing private satellite TV terminals. Price for *Coop's Satellite Digest* is $50 per year in U.S. and Canada, $75 (in U.S. funds) elsewhere via first class mail from: Coop's Satellite Digest, P.O. Box G, Arcadia, Ok. 73007.

Circuit Boards—A series of circuit boards are available for virtually all portions of the satellite TV receiver described in this series. Circuit board *IF-70A* provides the circuit necessary to create your own 70-MHz IF strip as described here, using the Motorola ART-120 device. Circuit board *DEMOD-TVRO* provides the layout for the 70-MHz-to-baseboard demodulator circuits described in this issue. For price and delivery contact: Robert M. Coleman. RFD 3. Box 58-A. Travelers Rest. SC 29690.

TV RECEIVERS
continued from page 18

high quality reception from the Russian stationary series of satellite transponders although he is working with signals 7-9 dB weaker than we have available here from North American domestic satellites, and he has acceptable (if not high quality) pictures from the much weaker Intelsat satellites (they run from 12 to 15 dB weaker than our domestic satellites). The balance of his receiver approach is pretty standard since once you have baseband video and audio there is only about one way to process it for conversion back to RF as an AM format signal.

To some people, being at baseband with the signal may seem like ending up at the wrong place. To view baseband directly, you feed the video and audio signals into a video "monitor" and a speaker. Not everyone has a video monitor of course and some means of getting the baseband signal back to a standard NTSC television channel (with the video portion amplitude modulated) is required.

A word about viewing the signal(s) at pure baseband; i.e. into and through a video monitor. This is the ultimate (high class) viewing technique since the baseband signals are of very high quality (48- to 54-dB signal to noise) and purity. However, this generally limits you to viewing the signals on a single monitor since video monitors tend to be expensive.

In Fig. 4 we have several methods suggested to get the baseband back to an RF channel. Clearly the baseband video and audio must be used to modulate a TV channel modulator device. Numerous circuits for these devices have appeared in **Radio-Electronics** through the years. One of the easiest ways to modulate back to RF is to use a LM1889 IC which is a complete (TV channel 3 or 4) RF carrier generator/modulator intended for TV games and home VTR's. If you already have a home VTR, you can simply loop the baseband video and audio to the home VTR's "camera" and "audio" inputs. This turns the VTR into a modulator for you and you can then watch the satellite TV signals on multiple TV receivers, connected to the VTR modulator through 75-ohm coaxial cable (as in a miniature TV distribution system). **R-E**

SATELLITE TV
continued from page 24

sive protractor can be used when adjusting the tilt angle.

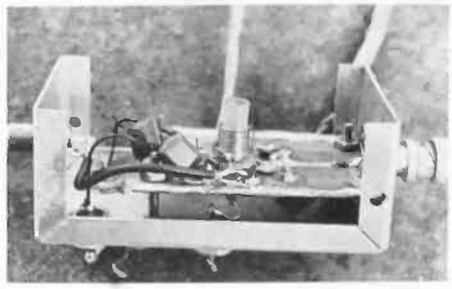
Remember that the spherical can look at signals off boresight ± 20 degrees and with a corresponding repositioning of the focus point antenna you can receive different satellites (or alternately look at more than one satellite simultaneously with multiple feed horns). The same thing is true with the vertical ('tilt') angle. It reciprocates. If at your location the angle of arrival of the incoming signal is 34 degrees and the reflector is vertical (perpendicular to the earth), the focused energy will leave the reflector going down towards the ground at a 34-degree angle as well. Since this would result in your having to point the feedhorn antenna 'up' at the reflector at a 34-degree angle, it might also result in your having to dig a hole in the ground to properly drop the feedhorn-antenna 1.5 times the antenna aperture away from the antenna. The obvious solution is to tilt the antenna back. If the antenna is tilted back 20 degrees (the base stays on the ground, the top tilts backward) then your 34-degree elevation arrival angle will leave the antenna at an angle of 14 degrees (34-20=14) with respect to the ground. This will raise the focus point up above ground level and reduce the upward tilt required for the feed antenna. In any case, the same ± 20-degree reception ability we find true with incoming signals left and right of the boresight line also holds true with the tilt angle. This simply says that you must have your tilt angle at least within 20 degrees of the highest arrival (elevation) angle of the incoming signals. A computer derived chart customized for your location was footnoted in the October 1979 issue. You need one before you can start laying out your antenna!

The feedhorn dimensions are given in Fig. 10. The feedhorn is flanged so as to mount directly to the type WR-229 waveguide flange found on the input side of most LNA's. Study the feedhorn drawing shown in Fig. 10 carefully and the photo in Fig. 11 Material is galvanized sheet metal and accuracy required is ± 0.1 inch.

Note: The preceding material may not prove sufficiently detailed for the novice in this field. The *Swan Spherical TVRO Antenna* manual is some 30 pages in length and provides complete step-by-step instructions for those uncomfortable with the brevity of this quick outline.

Next month we will give details on construction of the LNA (low noise amplifier) plus the VTO 8360 tunable oscillator and GaAs-FET active mixer assembly. **R-E**

TV RECEIVERS
continued from page 27



ACTIVE MIXER USING HFET device along with VTO 8360 (mounted out of sight on back side) mounts in single container. Unit can mount outside, at antenna, if appropriately weatherproofed thereby running only 70-MHz IF energy down and inside (in low-cost 50- or 75-ohm coaxial cable).

and are delivered at the output in the 70-MHz region. Inductor L1 plus capacitor C1 determine the IF resonance. With the value shown for L1, C1 will typically be around 5 pF. It is important that the Q of this output section be kept fairly low so that the full 30-MHz bandwidth of the 70-MHz IF signal gets out of the mixer and into the IF amplifier stages without being restricted. The 5K pot in the −4 VDC bias supply lead is adjusted for optimized performance simply by looking at the picture on the screen. This adjustment, plus the tuning voltage on the VTO 8360 are the only two real adjustments that you need to work with to get 4-GHz energy down to 70 MHz! Inductor L1 tunes broadly and can be optimized after the satellite signal is received.

This portion of the system can be tuned by using an MATV/CATV-type field-strength meter tuned in the 70-to-80 MHz region—or, in a pinch, you can actually run the 70-MHz IF output into a standard television receiver tuned to channel 4. No, you will not recover video (or audio); remember that the satellite TV format is FM, and 30-MHz or so wide FM at that, and consequently the 4.5-MHz wide TV IF set up to detect AM video modulation simply can't recover usable video. But, the TV receiver tuned to channel 4 can act as a "tuning indicator" of sorts, and if you happen to run across a transponder transmitting a static picture, such as color bars or a slide, you may for a brief instant even see something resembling a picture.

The circuit-board layout for the active mixer is available from Robert Coleman directly (address previously given) and a complete board ready to mount the parts on (including the VTO 8360) is also available for $25.

There: Getting from 4-GHz down to the 70-MHz IF was not all that difficult! Next month we will look at the IF-to-baseband circuits, as well as the RF remodulation back to a standard NTSC format for direct viewing on a standard television receiver. **R-E**