A WIDE BANDWIDTH TELEMETRY SYSTEM

David E. Henry and R. E. Glass
Transmission Systems Division 5223
Sandia Corporation
Albuquerque, New Mexico

SUMMARY

This paper will describe a telemetry system which has a bandwidth of 250 megacycles, the uses to which it has been put and possible future uses.

In its present state this is a 4,000 megacycle, pulse modulated FM system. At the receiver the RF is amplified to 0.5 watts; amplitude limited, and discriminated at this level.

This system has been used in the field since January 1955 and has proved to be quite reliable. Its use to date has been limited to measuring time intervals of 200 microseconds or less to an accuracy of 5 milli- microseconds, and to faithfully reproducing pulses requiring up to 250 mc bandpass.

Although this system has not yet been used as an air-to-ground telemeter, the transmitter components were designed to withstand environment of free-fall weapons.

Such a wide bandwidth system has considerable potential for use as a high capacity pulse code or FM/FM telemetering system.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
BACKGROUND

Sandia Corporation is continually faced with the necessity of making certain basic diagnostic measurements on full-scale weapon tests. Since, on occasion, these measurements are made on free-fall weapons, the telemetrying system must, of necessity, utilize an RF link. These measurements consist of the time intervals between several pulses occurring in a period of 200 microseconds or less, and the shape of these pulses. The required time interval accuracy is 5 millimicroseconds. In most cases a 40 mc bandwidth system is adequate to accurately reproduce pulse shapes, but occasions do arise when a bandwidth of 250 mc is required for pulse reproduction.

After investigating all available RF components, development of a 4,000 mc FM system was decided upon since at this frequency many components having the required characteristics for a 40 mc system were commercially available, and development of other components at this frequency had progressed to the extent that a 250 mc bandwidth system appeared feasible.

Both systems have been developed; and since January 1955, have been used in the field on ground-to-ground operations where they proved to be quite reliable. Only recently, however, has a full 250 mc bandwidth been achieved in the wider bandwidth system.

Although there has not yet been an opportunity to use these systems as an air-to-ground telemeter, the transmitter components were designed to withstand the environment of free-fall weapons.
Since several components are common to both, the 40 mc bandwidth system will be described first, and then the changes necessary to convert it to a 250 mc bandwidth system.

40 MC SYSTEM COMPONENTS

Transmitter

The transmitter is a Western Electric 431A reflex klystron. It is operated in the 1-3/4 mode and is frequency modulated by coupling the information pulses to the reflector element. Power output is 400 milliwatts ± 1.5 db over approximately a 40 mc frequency shift. Its deviation rate is also about 40 mc. Modulation sensitivity is 0.6 mc/volt. Figure 1 shows a dual transmitter package designed for an airborne application.

Transmitter Power Supply

The power supply is transistorized. It requires a nominal 28 v. input and the output voltages vary less than 1% with an input variation of ± 2 volts. Its volume is approximately 50 cubic inches.

Antennas

Three types of transmitting antennas have been used: a horn approximately 3 ft. long having a gain of 20 db, a 6 ft. parabolic dish with a gain of 35 db, and a 10 ft. 40 db gain dish. In all cases the receiving antenna has been a 10 ft. dish.

Receiver

The receiver consists solely of RF amplifiers and a discriminator. The first two stages are Bell Telephone Laboratory type 1819 traveling
wave tube amplifiers that have a noise figure at 4,000 mc of 8 db, a
gain of 15 db, and a bandwidth of 800 mc. Following the TWT amplifiers
there are, depending upon the particular gain requirements, five to seven
stages of series tuned Western Electric 416B cavity amplifiers. The noise
figure of a 416B stage is 16 to 20 db. The gain and bandwidth of a single
stage is 10 db and 150 mc respectively for a low level input. As the in-
put level to a given stage approaches its maximum output (0.5 watts) the
tube gain decreases and the tube is said to be in compression. This situa-
tion is deliberately incurred in order that the last stage or two of 416B's
might act as limiters ahead of the discriminator.

The output of the last 416B is divided by a waveguide hybrid junction
and fed to each arm of the discriminator through a uniline. The uniline
is a waveguide section having the property of transmitting RF energy es-
sentially in one direction only. Actually there is an attenuation in the
forward direction of 1.5 db and of 20 to 25 db in the reverse direction.
Its operation is based on the "Faraday" effect. Beginning at the uniline
output (see Fig. 2), each discriminator arm consists of: a section of
coax cable, two double stub coaxial tuners, a coaxially mounted crystal,
and another section of coax cable. The two crystals are mounted so that,
as viewed from their respective unilines, they are of opposite polarity.
The open ends of each arm are terminated through a tee connector to a
common load which is the 120 ohm input of a video amplifier. The double
stub tuners of one arm are adjusted to match the combined impedances of
the tuners, crystal, and amplifier input to the arm at a frequency that is
just above the carrier frequency. The same thing is done in the other arm
at a frequency that is below the carrier by a little more than the maximum required deviation. It is now seen that the algebraic sum of the rectified crystal currents versus frequency as seen by the video amplifier input is a discriminator curve. (See Fig. 3).

Display and Recording Equipment

The discriminator output is displayed on a raster oscilloscope that is capable of presenting a maximum of 35 traces at a maximum speed of 2.5 microseconds/trace. There are ten time markers on each trace. The first pulse received triggers the scope which then displays the complete pulse train on one continuous time base. When, for the sake of more accurate record evaluation, it is desired to expand certain portions of the raster presentation, the discriminator output is also fed to a Tektronix 517 oscilloscope. Trigger times of this scope are determined with reference to the first pulse of the train. Circuitry has been added to give vertical trace separation. The raster time markers are imposed on this display in order to preserve a reference for the measurement of time between pulses on separate traces. These displays are recorded by 35 mm moving strip cameras to minimize the possibility that noise triggered traces will mask the desired information.

250 MC SYSTEM COMPONENTS

The components limiting the bandwidth of the 40 mc system are: the transmitter, final RF amplifier stages, video amplifiers, and oscilloscopes. A description of the substitute components that raise the overall system bandwidth to 250 mc now follows.
Transmitter

The transmitter tube is a General Electric Voltage Tunable Interdigital Minimagnetron. It operates at a nominal 4,000 mc and is frequency modulated by coupling the information pulses to the cathode element. Power output is 5 w. ± 1.5 db over 400 mc of frequency shift. Deviation sensitivity is 2 1/2 to 3 mc/volt. The deviation rate of this transmitter is extremely high and is apparently limited only by the stray capacitance of the modulation input circuitry. At the present time, the only portion of the minimag power supply that is transistorized is an input regulated B- supply (40 ma at 1200 v.). In its present state, this transmitter package is quite bulky compared to the klystron, but it is anticipated that the weight and volume will be limited to 15 pounds and 150 cubic inches respectively.

Receiver

In changing from a 40 to 250 mc bandwidth system, it was necessary to modify the receiver as follows:

1. The series tuned 416B stages were replaced by two traveling wave tube amplifiers of equivalent gain. These are a modified type 6495 medium level - Sylvania TWT amplifier and the Hewlitt-Packard 491A high level TWT amplifier.

2. Following the 491A are three stages of stagger tuned 416B amplifiers. These serve two purposes:

   (a) Their compression characteristics provide the desired limiting action ahead of the discriminator.

   (b) Provide the desired bandwidth by limiting the extremely wide bandwidth characteristics of the traveling wave tube amplifiers.
Because of the stagger tuning, it was necessary to precede each 416B stage with a uniline in order to achieve some degree of independence in tuning the amplifier cavities.

3. The same discriminator components are used, but by readjusting the stub tuners a discriminator curve of good linearity and approximately 150 mc peak-to-peak is obtained.

**Display System**

The raster presentation is retained for time measurements, but the Tektronix 517 scope is replaced with an Edgerton, Germeshausen & Grier traveling wave oscilloscope driven by a Spencer-Kennedy Laboratory 300 mc chain pulse amplifier. This oscilloscope has a 2,000 mc bandwidth, $10^8$ in/sec maximum trace speed, a 0.001-inch spot diameter and maximum vertical displacement of 0.3 in. Its presentation is recorded by a special Edgerton, Germeshausen & Grier camera.

**SOME NOTES ON POSSIBLE SYSTEM COMBINATIONS AND USES**

As the reader may have observed, a receiver bandwidth of greater than 40 mc is required to fully utilize the 40 mc deviation rate of the 431A klystron. The increase in bandwidth is easily gained by replacing three 416B amplifier stages with the Sylvania 6495 TWT amplifier. For that matter, a system of any desired bandwidth up to 250 mc can be assembled from the components already described.

On all programs where this system has been used, dual channels have been employed for increased reliability. The transmitter outputs were
diplexed into one antenna. The RF system was common to both channels from this transmitting antenna to the output of the second Bell Laboratory TWT amplifier. This is true for all three possible combinations of narrow and wide band channels except that two transmitting antennas were used when both channels were wide band.

No filtering is necessary at the receiver since the two center frequencies are displaced far enough that the selectivity of the 416B amplifier stages is sufficient to reject the unwanted channel.

The transmission range of this system will vary according to individual test requirements of bandwidth, signal to noise ratio, and transmitting antenna gain. For ground-to-ground operation where a high gain transmitting antenna can be used, the achievement of line of sight is the only real limiting factor. For air-to-ground operations the range will vary from 5 to 100 miles.

The potential of this system for transmitting any high capacity pulse code or FM/FM modulation, or any combination of the two, is far greater than any foreseeable need.

Conclusions

This microwave wide band telemetering system has been successfully used on ground-to-ground operations where bandwidths of 40 to 250 mc were required to measure time intervals and to reproduce pulse shapes. It may be used on air-to-ground operations for making these same measurements over maximum transmission distances of 5 to 100 miles. It is potentially useful for transmitting high capacity pulse code, FM/FM, or combination pulse code FM/FM modulation.
FIGURE 2  4 KMC DISCRIMINATOR
DISCRIMINATOR CURRENT
VERSUS FREQUENCY

FIGURE 3