WIRELESS TV VIEWER RESPONSE

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ABSTRACT

For over 20 years, the cable television industry has sought a cost effective way to retrieve real-time information from the home. Recent laboratory and field tests have demonstrated the suitability of over-the-air radio transmission as an alternative way to received pay-per-view and other data from subscribers' homes. The new system uses bandwidth efficient pulsing to achieve high speed viewer polling, (upwards from 784,000 per minute; nominally 945,000 per minute), without two-way cable or telephone connections. The TV Answer System is currently being tested at Media General Cable in Fairfax, Virginia. In addition, the Federal Communications Commission is considering the allocation of one-half MHZ in the 216 to 222 MHZ band for the use of this new viewer response service. Field tests are now underway to support a petition for formal rulemaking.

THE TV ANSWER SYSTEM

The TV Answer System utilizes a radio transmitter, "the TV Answer Box," in each subscriber's home. The household transmitter is polled via data inserted in the forward video signal, just off screen in the over-scanned television receiver. The first 5 microseconds of each horizontal line are used to transmit one bit. The initial 24 lines identify the polled group and transport other useful information from headend to home unit. The polling bits, plus the horizontal synchronizing pulses, tell the units when to transmit their locally stored data. In each home one bit is transmitted each polling cycle. At one bit per horizontal line, capacity exceeds 900,000 bits per minute. In the present implementation of TV Answer, the vertical interval is avoided, and, allowing for some over-the-air transmission time, 784,000 bits-per-minute capacity is achieved. For simple Yes/No questions like, "Do you wish to watch this movie?" 784,000 homes per minute can be polled. Future generations of the box may allow for multiple pulses per horizontal line. This will allow over 1,000,000 responses per minute.

Figure 1, reprinted from Figure 6 of US Patent 4,591,906, shows the location of the forward addressing pulses. The pulses are off-screen on the television receiver. If a receiver were intentionally underscanned, they would appear as a black and white vertical strip on the left side of the screen. Since the data are actually "in the video" (albeit off-screen), the vertical interval is left available for other uses. One disadvantage of this method, presently unstudied, is that horizontal timing information must be available to address the home unit. This means that, at the present at least, the TV Answer addressing channel cannot be scrambled. In the Media General test situation, an unscrambled "ordering channel" is used. In home shopping and direct response situations, as well as opinion polls, games or educational uses, this poses no problem. If an ordering channel is not available because channel space is tight, an

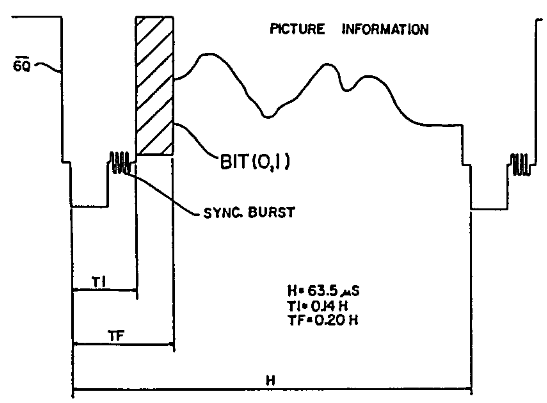


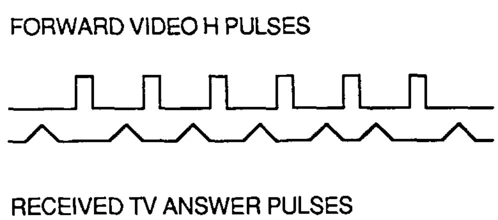
Figure 1 - Location of Forward Addressing Bits

ordering interval, with unscrambled video might be used. To address the TV Answer Box, a 5 to 15 minute unscrambled period might be necessary, for example, before a movie or event. This problem will be studied further as the product is developed.

The return pulses are timed to reach the central computer located at the headend or studio in a continuous stream. Boxes more distant from the receive antenna anticipate the delay and launch their pulses early. A numerical value proportional to the delay is stored in each box during a "calibration cycle". This cycle corrects for the delays of the forward transmission system as well as the return pulse transmission time.

Figure 2 shows the normal transmission system as seen at the central receiving point: a continuous stream of pulses, synchronized by the forward video horizontal "sync."

FIGURE 2 - RECEIVED PULSE SYNCHRONIZATION

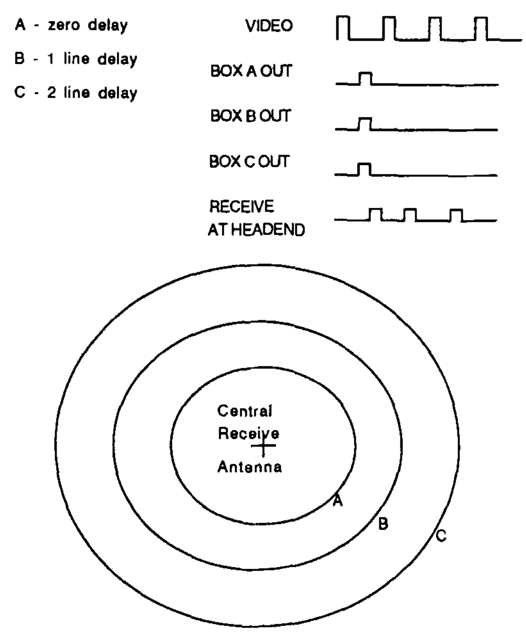


During the calibration mode, 5 horizontal lines are left unused after each request for a poll. Each unit, then, has 5 times 63 microseconds, i.e. 315 microseconds, in which to respond. When the pulse is received, the value of the delay is sent to the home unit for local storage. Thus, if a distant location takes 300 microseconds to respond, the TV Answer Box will transmit 300 microseconds early in order to arrive at the central antenna at the proper time. A close-in box would transmit with nearly zero delay. Figure 3, illustrates this point. If one unit in each zone transmits at the same instant, pulses would arrive as a continuous stream at the central antenna. The calibration cycle takes 5 times as long as a normal cycle. Figure 4 shows the calibration cycle. Figure 5 shows the normal cycle. Note the 5 blank lines before the first box response is received. This allows that unit to be at the farthest extreme in the transmission area. The calibration cycle can be run as often as necessary when questions are not being asked.

The home units are grouped 200 at a time. The addressing can reach all 200 boxes at once with one address. Each unit then begins counting horizontal synchronizing pulses to know when to transmit. In the present configuration, 4 bits are stored locally. Thus, a question, could have 4 multiple choice answers, and four cycles would be needed to get all the information. The forward bits also tell when a question is being asked, and communicate when to clear memory. The home unit will only transmit when a question is asked from the headend.

Multiple channels can share the same return frequency by coordinating the timing of the retrieval of pulses. Since the forward polling is through the video, only the boxes watching the channel that is asking questions will respond. Computer software is being developed to coordinate the forward pulse insertion, and data retrieval process.

FIGURE 3 - DELAY FROM HOME TRANSMITTERS



PROPAGATION ISSUES

The forward signalling system over a cable system or over-the-air is relatively controlled and predictable. The return signal is severely attenuated in the return journey as a result of man-made structures and natural terrain. The receive antenna must be able to distinguish the pulse from man-made and natural noise. While the propagation concerns seem to require the largest transmitter possible, interference issues require a suitable frequency which will not interfere with existing services, yet allow an economically efficient transmitter.

Efforts so far have concentrated on 216.25, 218.25, and 220.25 MHz. These frequencies were chosen because they are presently underutilized due to potential interference to Channel 13. They also allow construction of a reasonably priced in-home transmitter.

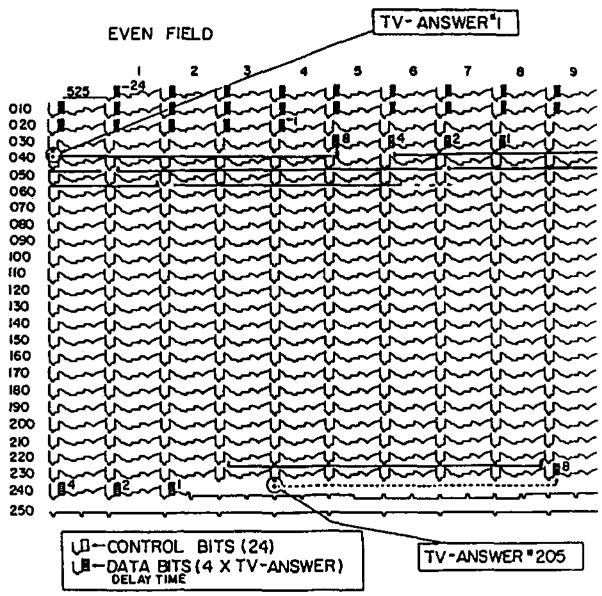


FIGURE 4 - CALIBRATION CYCLE

Pulses received within 5 line window at headend depending on transmission time.

TECHNICAL TESTS

The shaping and random nature of TV Answer's pulses lend themselves to a statistical analysis of interference. Present testing is intended to measure the effects of these pulses in television receivers, and model the potential problems. Two of the major tests presently underway are:

1. An analysis of the susceptibility of television receivers to interference at 216.25, 218.25 and 220.25 MHz., and,

2. Measurements of the time average power delivered by actual units in subscriber's homes spread across a geographic area.

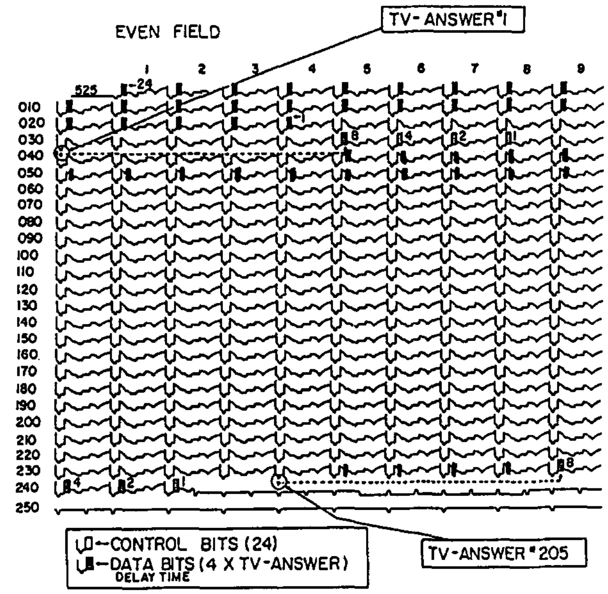


FIGURE 5 - QUESTION CYCLE

Pulses received every video line at headend

BACKGROUND

The 216-220 MHz. band is presently underutilized due to potential interference to Channel 13. The rules for creating a band for "Viewer Response Television" require an engineering determination of the potential for interference.

Figure 6 shows the parts of a transmission model for exploring the potential for interference.

Measurements of the susceptibility to interference to television receivers were performed in 1975, (see Reference #4). TV Answer has repeated these tests on 30 modern receivers for both CW and the actual TV Answer pulses using the equipment shown in Figure 7. A second test involves placing TV Answer Boxes in homes and measuring the accumulated power from a cluster of homes over time. Each unit transmits in its own time slot, only one pulse at a time is launched. However, pulses are launched to reach the headend one horizontal

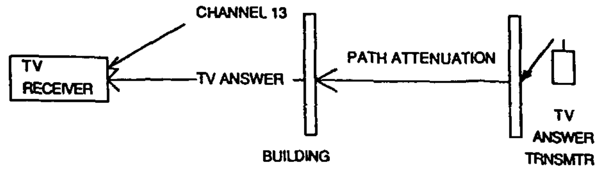
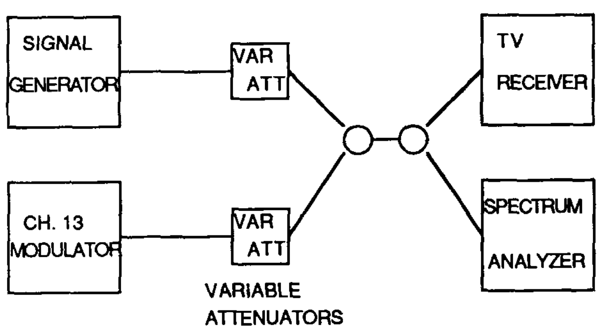


FIGURE 6 - INTERFERENCE TRANSMISSION

line apart. The more distant pulses are transmitted to overcome the delay in getting back to the headend. The transmit antenna is omni-directional and signals radiate outward in concentric circles. At any point in the system pulses may converge in or out of phase in a random pattern. Not all of the units transmit on every cycle. Interference then must be statistically modeled.

TV Interference was measured at three frequencies: 216.25, 218.25 and 220.25 MHz. The visually displayed pattern varied from TV receiver to receiver. TV receivers were generally more affected by 216.25 than 218.25 or 220.25, as expected. Additionally, the effects of 220.25 MHz (2 times 4.5 MHz above Channel 13's picture carrier.) on sound and AFC were observed in TV receivers using 4.5 MHz. internally. For these functions, the receivers was often confused by the 4.5 MHz beat between the interfering signal and sound.

FIGURE 7 - TV SUSCEPTIBILITY MEASUREMENTS



CENTRAL RECEIVING ANTENNA

The centralized receiving point must be able to receive levels down to about -90 dBm, based on preliminary path calculations and actual measurements. The economics favor improvements at the one receiver rather than the many transmitters.

This type of reception array problem should not be new to any cable television engineer. We need to find a low level pulse above man-made and natural noise near Channel 13. The present receive configuration consists of a +10 dB gain , 215-225 Mhz. whip antenna, 300' of cable, a 30 dB pre-amplifier, a 1 MHz wide cavity filter, and a communications receiver with a 200 KHz IF bandwidth. The overall configuration will detect signals down to a signal-to-noise of +10 dB above the receive equipment noise floor of -116 dBm .

FCC PROCEEDURES

In 1987, TV Answer Inc. began field testing under controlled conditions, to develop a feasible transmit/receive configuration using a temporary license granted by the Federal Communications Commission. In December 1987, we petitioned the FCC to begin a formal rulemaking on the permanent allocation of one-half Mhz, nation wide, to support "viewer response" television. As of the publication of this paper, the FCC is still deciding whether to begin that formal rulemaking.

One-half Mhz. seems a small amount of spectrum to allocate in order to achieve something that has been talked about for over 20 years, but never before accomplished. In various forms, two-way cable and telephone interconnection have produced disappointing attempts to give the public an ability to interact with television programming. Wireless transmission offers a solution to the problems other technologies have been unable to overcome.

TV Answer continues to test and develop its product, and work with industry and government to document the utility of the "Viewer Response" electromagnetic band.

Mr. Dattner is President of DAI, a Telecommunications Engineering Firm, and a Senior Engineering Consultant to TV Answer Inc. of McLean, Virginia. He has 17 years experience in cable television including Media General Cable of Fairfax, Virginia and a major cable television manufacturer. He has a Masters degree in System Engineering and is working on a Masters degree in Business Administration.

Note: Due to publishing deadlines, this paper does not contain the results of field tests presently (March, April 1988) being conducted. For more information contact the author or TV Answer, Inc., 8201 Greensboro Drive, McLean Virginia, 22102, (703) 356-7800.

REFERENCES

1. Eckert, R. "Guidance for Evaluating the Potential for Interference to TV From Stations of Inland Waterways Communications Systems" OST Technical Memorandum, FCC/OST TM8 2-5, July 1982.

2. Federal Communications Commission, Third Notice of Further Proposed Rulemaking, "Television Broadcast Services," Federal Register, Vol. 16, No. 68, Page 3072, U.S. Government Printing Office, Washington, D.C., April 7, 1951.

3. Goldberg, Henry and Jeffrey H. Olson. "Petition for Rulemaking". In the Matter of TV Answer inc., before the Federal Communications Commission:", Washington, D.C. December 2, 1987.

4. L. Middlekamp, H. Davis, "Interference to TV Channels 11 and 13 from Transmitters Operating at 216-225 MHz., FCC Lab Division Report, Project No. 2229-71, Oct. 1975.

5. United States Patent 4,591,906, issued May 27, 1986.

APPENDIX

(This section is based on "Guidance for Evaluating the Potential Interference to T V From Stations of Inland Waterways Communications Systems," by R. Eckert, OST Technical Memorandum, FCC/OST TM82-5, July 1982.)

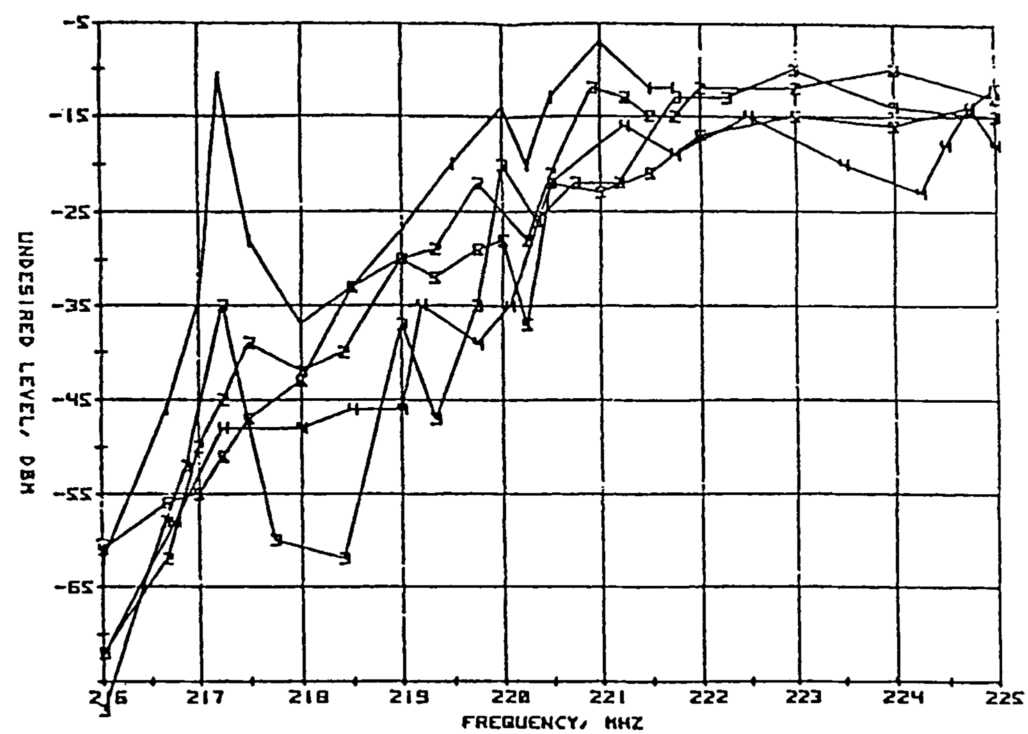


Figure 8 - CW Interference Susceptibility
(See Reference 4)

One important factor in the decision by the Federal Communications Commission to create a "viewer response" radio band, or not, will be the susceptibility of television receivers to interference at 216.25, 218.25, or 220.25 MHz.

A review of the FCC's bench test (see the data in Reference #4, reproduced here) produces the following minimum ratios for an input level of -65 dBm:

Protection Ratios (dB) for Just Perceptible Interference

Frequency	Desired to Undesired Signal Ratio
216.25 MHz.	+ 5 dB
218.25 MHz.	-15 dB
220.25 MHz.	-25 dB

These ratios are for CW signals on a small sample of receivers (5). The ratio chosen is for the most susceptible receiver. TV Answer is presently compiling data on receivers and the effects of the TV Answer shaped pulses.

To identify possible interference, it is necessary to statistically account for the time variation of the desired Channell3 signal and the undesired pulses. A log-normal distribution is assumed to account for terrain variations. In the analysis below, the objective is to determine the percentage of locations, L, at which there will be interference free reception T % of the time.

The desired condition of no interference occurs when the ratio of wanted to unwanted signals is better than the barely perceptible ratio in the chart above. Figure 19 of the FCC Report predicts the signal level for 50 % ofthe Television Receivers, 50 % of the time, F (50,50), based on antenna heights and distance. Figure 20 of the same report gives analogous data for 50 % of the Television Receivers, 10 % of the time, F (50,10). A fading ratio can be calculated from subtracting the two curves. These three curves are reproduced in Reference #1, and on the next three pages. Variability of the signal is accounted for by using a log-normal distribution with a standard deviation of 8.6 dB. This means that there is a 90% chance that signal variations will be as large as 11 dB.

To combine the fading factors of the desired and undesired signals, the square root of the sum of the squares is used, based on the assumption of uncorrelated distributions.

The percentage of homes, L, at which there will be no perceptible interference can be determined from the following equation:

$$R(L,G) = A + P_u - P_d + F_u(50,50) - F_d(50,50) + \sqrt{R_d^2(T) + R_u^2(T)}$$

where,

A = Minimum acceptable desired to undesired ratio in dB between the fields.

$R_d(T) = F_d(50,T) - F_d(50,50)$, depth of fading in dB

$R_u(T) = F_u(50,T) - F_u(50,50)$, depth of fading in dB

$\sqrt{R_d^2(T) + R_u^2(T)}$ -- Variation with time combination in dB

P_u = Undesired, pulse - effective radiated power in dB above 1 kilowatt radiated from a half-wave dipole,

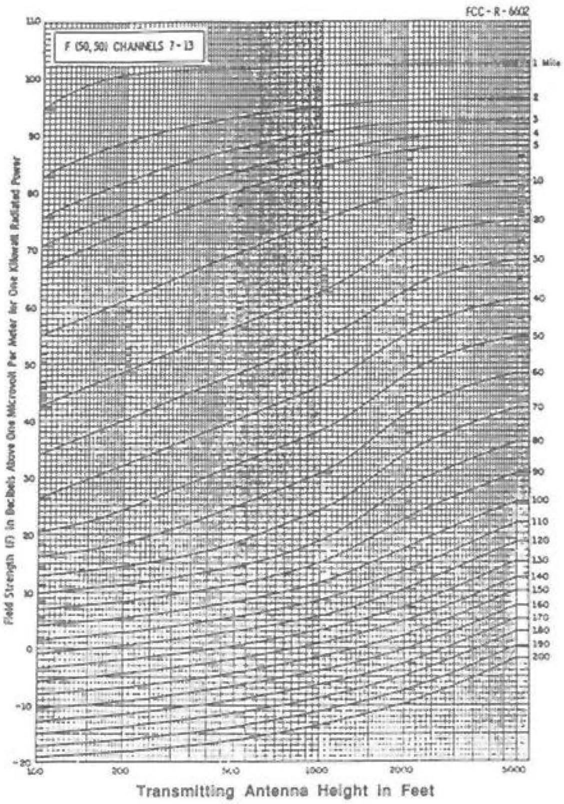
P_d = Desired (Channel 13) signal, effective radiated power in dB above 1 kilowatt radiated from a half-wave dipole,

F(50,T) is in units of dB(uV/m),

$G = F_d(50,T) - F_s$,

where F_s = the minimum TV Field strength for service.

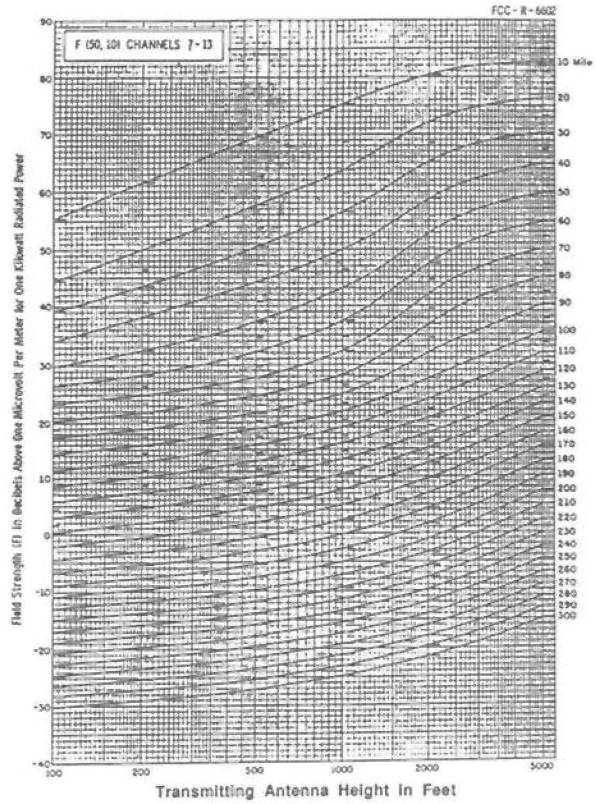
By applying the distributions of F_d and F_u, it is possible to create a graph of potential interference based on distance and antenna heights. Figure C-1 from Reference #1 is reproduced here to give an example of potential interference area calculations. The TV Answer task is complicated by the inclusion of losses created by man-made objects as well.



Television Channels 7 - 13
Estimated Field Strength Exceeded at 50 Percent
of the Potential Reciver Locations for at Least 50 Percent
of the Time at a Receiving Antenna Height of 30 Feet

April 12, 1966

Figure 19



Television Channels 7 - 13
Estimated Field Strength Exceeded at 50 Percent
of the Potential Receiver Locations for at Least 10 Percent
of the Time at a Receiving Antenna Height of 30 Feet

April 12, 1966

Figure 20

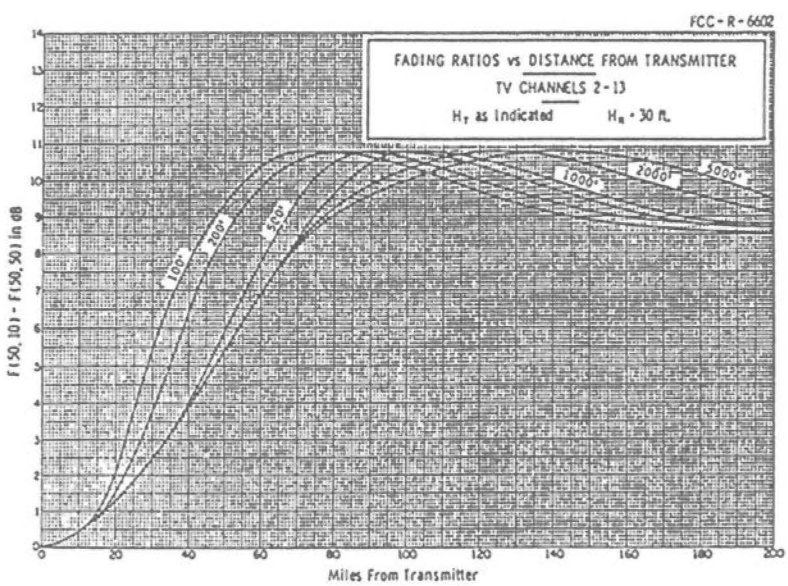
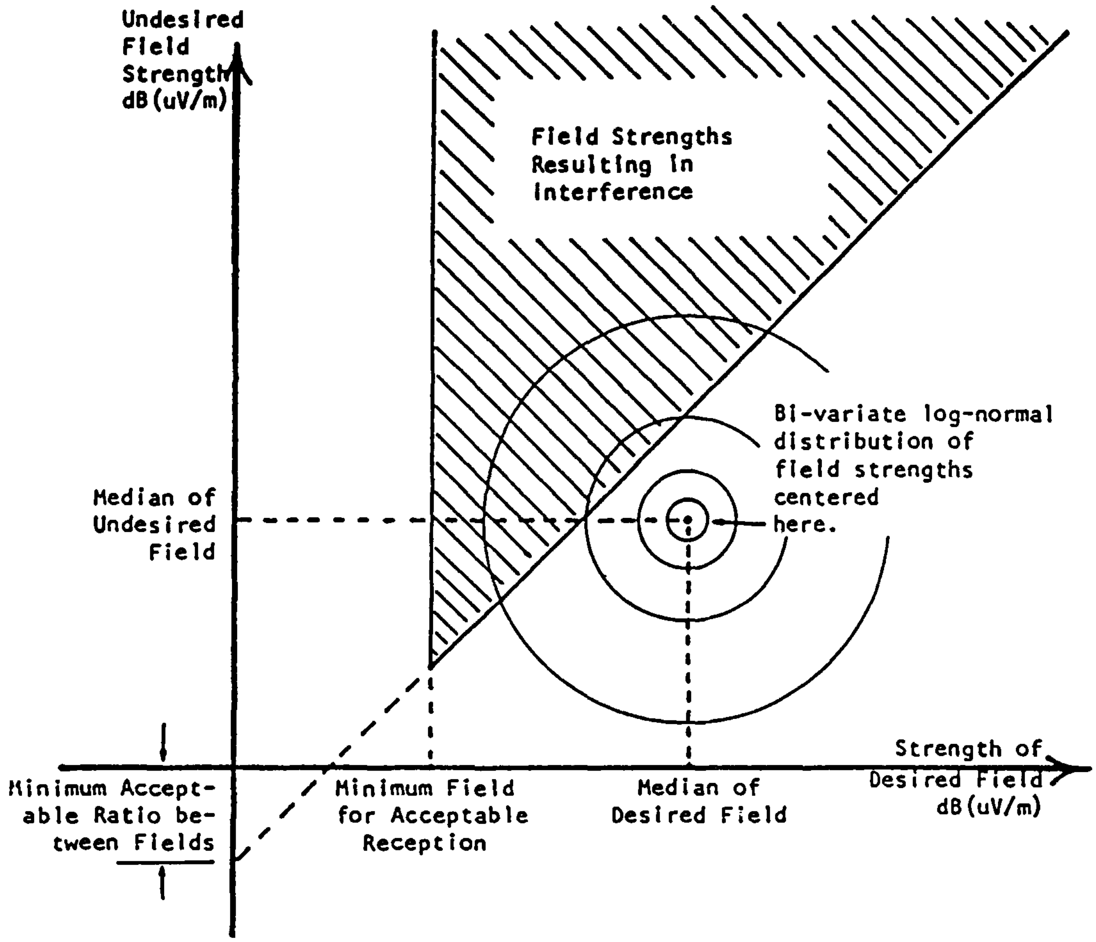


FIGURE 10



GRAPHICAL ANALYSIS OF RECEPTION AND INTERFERENCE CONDITIONS

FIGURE C-1