THE GREAT FREQUENCY DEVIATION AUTOMATIC MEASURING OF TELEMETRY TRANSMITTER

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ABSTRACT

At present, there is no means of instrument direct measurement to frequency deviation when it is up 500kHz. But the frequency deviation of high bit rate telemetry transmitter is 700kHz or more. In this paper, an indirect measurement method using spectrum analyzer and counter is put forward. It effectively solves the measurement problem of frequency deviation and frequency response of high bit rate telemetry transmitters. Measuring theory, summary of experiences and difficulties in measuring work, have been deeply studied with the viewpoint of how to avoid the limitation of different methods of measurement. Focused on the establishment of an automatic measuring system, expert system, skilled data and software of the system are studied in detail. The data for comparison is also supplied. Finally, the analysis to the measuring error and general uncertainty is given.

KEY WORDS

Telemetry Transmitter, Frequency Modulation, Frequency Deviation Measurement, Expert System (ES), Data Structure

PREFACE

With the incessant development of flying machine technology in the astronautic field, capacity of information transmitting is highly requested. Frequency modulation system not only has great capacity and micro distortion in information transmitting, but also has powerful anti-jamming abilities. So it has been mostly adopted in the astronautic telemetry field. To meet the requirement of information capacity, a great frequency deviation modulating system should be adopted.

At present, the frequency deviation measure instrument in the international range can only catch the frequency deviation, which is under 500kHz. But in the practical applications the frequency deviation may be 700kHz, or even 1M, 2MHz. As direct measurement by instruments can not handle such great quantum, only indirect measurement method can be used. The research which is based on the analysis of frequency modulation waves characteristics, try to find out the relationship between frequency deviation and other parameters. After measuring other parameters under certain conditions, we can calculate the frequency deviation through certain expressions. The measuring precision of the other parameters can be very high, so it makes the measurement of great frequency deviation feasible.

The measuring method for great frequency deviation through indirect way is a very complex testing system. Rich experienced engineers and technicians should also be demanded through the whole debugging process. It has a great sense of engineering, and it's calculating process is much detailed and troublesome. All of these seems quite difficult and need a long time for measuring.

The uninterrupted maturing and perfecting of automatic measuring system nowadays gives a revolutionary shock to electrical measurement. Computers in a measuring system no longer simply imitate the artificial measuring process and provide simple instructions and controls. Their ability has been brought into full play so as to strengthen the system's ability of real time control, logical judgement, data storage and mathematical operations. Especially, computer can directly join in the work of analysis to the measuring characteristics. Powerful computer software can replace some hardware of traditional instruments. Also, computer can provide some functions that can not be provided by some instruments. At this time, computer is playing a role as practical measuring technical personnel. Its measuring software can completely simulate the thought of the measuring personnel. It can choice a measuring method and takes proper steps by the judgement of the instruments' statement and the measuring data. In fact, it can be deemed as a miniature Expert System. Our laboratory in the Telemetric Center has already successfully applied the automatic measuring technology to great frequency deviation measurement, and built up a great frequency deviation automatic measuring system. So, by the cooperation of computer software and traditional hardware, the problems of means by hardware can be easily solved. It can effectively take charge in the great frequency deviation measurement of high code-rate, gives technical standard to great frequency deviation measurement and can be used by common measuring personnel.

MEASURING PRINCIPLE

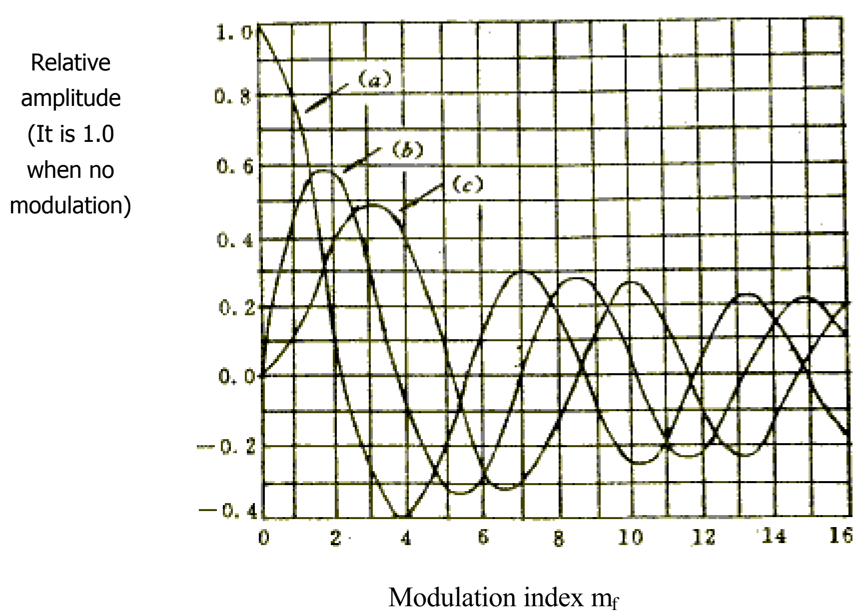
According to the measurement mission requirement and the laboratory conditions, this measuring system adopts Bessel function zero value method, counter method and amplitude comparison method. Among them, the Bessel function zero value method can give the highest measurement precision.

1.1 Bessel function zero value method

The spectrum expand expression of frequency modulation wave is

$$
\begin{aligned}
U(t) &= U\{J_0(m_f)\cos w_c t \\
&+ J_1(m_f)[\cos(w_c+\Omega)t - \cos(w_c-\Omega)t] \\
&+ J_2(m_f)[\cos(w_c+2\Omega)t - \cos(w_c-2\Omega)t] \\
&+ J_3(m_f)[\cos(w_c+3\Omega)t - \cos(w_c-3\Omega)t] \\
&+ \ldots\ldots\}
\end{aligned}
$$

While $J_n(m_f)$ is nth order first class Bessel function of which the independent variable is m_f. From this expression we can know that except angular frequency of carrier wave, the spectrum of frequency modulation wave involves lots of side band. The interval of side band is $f_m(f_m=\Omega/2\pi)$. The amplitude is determined by every order Bessel function $J_n(m_f)$ value. Of them, the variance rule of every order Bessel function $J_n(m_f)$ along with frequency modulation index m_f is shown in figure 1.



(a) carrier wave (b) first order side band component
(c) second order side band component

Figure 1. $J_n(m_f)$ Bessel Function Curve

From the figure we can know when m_f in some values, the value of every order Bessel function $J_n(m_f)$ will be zero. Then $U_n=UJ_n(m_f)=0$. Namely the amplitude of that frequency point is zero, so that frequency will disappear on the display. These can be look-up from Bessel function table, modulation frequency Fm can be accurately measured by cymometer. So from the equation:

$$\Delta f = m_f \times f_m$$

high precision degree frequency deviation value can be calculated. These are the theory bases of the Bessel function zero value method to measure frequency deviation.

In practical measurement, we change the modulation frequency to find the zero point. One common easy way is to look for the zero value point of the zero order Bessel function, that is the minimum of carrier wave under different modulation frequency. The key point is to find the zero value. Because of the lack of theory and practical experience of the measuring personnel, sometimes the found zero value is not the real minimum, or can not confirm which zero point the found zero point is. Also because of the bad capability of the products, the frequency spectrum may be not pure. Even the generated parasitic modulation can make the zero point faint. All of these carry great difficulty to the practice of measuring method. All of the problems above should be solved by high level technical staffs with practical engineering experience. Elementary measuring personnel can not deal with the operation.

1.2 Amplitude Comparison Method

According as the spectrum expands expression of frequency modulation wave, each spectrum amplitude is decided by every order Bessel function $J_n(m_f)$. And the value of $J_n(m_f)$ can also be calculated from the value of m_f by the following equation

$$J_n(m_f) = \sum_{k=0}^{x} (-1)^k \frac{1}{K!(n+k)!} \left(\frac{m_f}{2}\right)^{2k+n} \approx \sqrt{\frac{2}{pm_f}} \cos\left(m_f - \frac{1}{2}np - \frac{p}{4}\right)$$

So there is some corresponding relationship between $J_n(m_f)$ and m_f, that is $J_n(m_f)$ can be acquired from m_f. When $J_n(m_f)$ is given, the value of m_f can be look-up from a calculated table. Nay, to a certain m_f value, not only $J_n(m_f)$ has an affirmative value, but also the ratio of

$$\frac{J_1(m_f)}{J_0(m_f)}, \quad \frac{J_0(m_f)}{J_0(0)}, \quad \frac{J_2(m_f)}{J_0(0)} \cdot \ \cdot \ \cdot$$

is terminated. So if each specific value is known, the m_f value can also be checked out. From the following equation

$$\Delta f = m_f \times f_m$$

(in which Fm is very easy to be measured out), the frequency deviation can be calculated out. But from figure 1 we can know, when m_f is greater than 2.4, Jn is multi-valued while a function value corresponds to several independent variables m_f. So one specific value also has several m_f. to correspond. That brings difficulty to the measuring. Criterion must be added to confirm a m_f. by several specific values.

In practical measurement, to avoid the multi-valued Bessel function, m_f. in the range of less than 2.4 is adopted in measuring. The spectrum line shown by the spectrum apparatus is power density spectrum with tactic symmetry while carrier wave is the centre. By the spectrum instrument's great dynamic range and high precision characteristic, the relative value a(dB) between carrier wave component $J_0(m_f.)$ and first order side band component $J_1(m_f.)$ can be accurately and expediently measured. From the following equation $J_0(m_f.)/J_1(m_f.)$ can be gained.

$$a(dB) = 10\log J_0(m_f) - 10\log J_1(m_f) = 20\log[J_0(m_f)/J_1(m_f)]$$

Then the frequency deviation can be determined according as the principle given.

1.3 Counter Method
Counter Method is to measure the frequency deviation using electronic counter. Its principle figure is in figure 2:

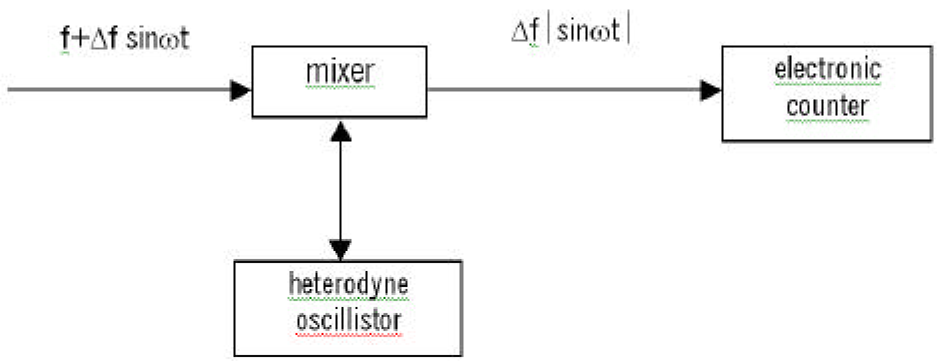


Figure 2. Counter Method Principle Diagram

The frequency modulation signal is produced by a mixer whose input are two synchronous signals of f+Δf sinωt and heterodyne oscillistor output signal of f frequency. When there's no modulation, the mixer has no frequency difference signal output, the counter value is zero; when there's a modulation, a heterodyne frequency signal Δf | sinwτ | is exist, the counter will measure out it's value. In a modulation signal period, the value N displayed by the counter is:

$$N = \frac{1}{T}\int_0^T \Delta f|\sin\Omega t|dt = 2\Delta f/p$$

$$Then: \quad \Delta f = Np/2$$

So the frequency deviation of frequency modulation signal can be calculated from the reading N of the counter.

According to the above, the measurement of great frequency deviation is quite a complicated process. Bessel function zero value method has a most highly precision, but it can only be used on several fixed modulation indexes and can not work on other modulation indexes. Amplitude comparison method can easily and directly look up modulation index by function value (the difference of frequency amplitude) in the modulation index range of less than 2.4. But when the modulation index is greater than 2.4, because of the multi-valued of Bessel function, one amplitude specific value has several corresponding m_f values and several more pare of side band often needed to be measured, using several specific values to look for one m_f. So the precision would be influenced. Those two methods both have some difficulty in measuring frequency deviation of large modulation index. The difficulty is produced by the instrument's own precision and resolving power, so the frequency deviation measurement with modulation index greater than 15 should adopt the counter method. Integrate the three methods, diversified great frequency deviation measurement can be completed, and the frequency response measurement can also be processed. That is, to different modulation frequency, measure the frequency deviation of modulator and protract frequency response curve. That is very important when the modulation signal is bogus stochastic code. Figure 3 is the system connection figure.

AUTOMATIC MEASURING SYSTEM

The measuring of frequency deviation relates to many instruments, the metric method is very complicated, and the data computation and handling is much detailed and complex. Especially, when measuring frequency response, person in charge of operation must be high level technical personnel with much experience, shall be very familiar to the instruments, and must know very clearly about the metric method. Also, a long measuring time is needed. However, computer can easily complete all these missions.

The great frequency deviation measuring system in our telemetric center laboratory uses the following instruments: Frequency Spectrum Analysis Apparatus HP8566B, Low Frequency Signal Generator HP3325B, Frequency Counter HP5340A, Frequency Synchronizer WILLTRON6747B and HP8671B, Multiplexer HP3488, etc. All the instruments have HP-IB interfaces and programmable functions, so an automatic measuring system can be easily founded. The flowchart of the program is shown in Fig. 4.

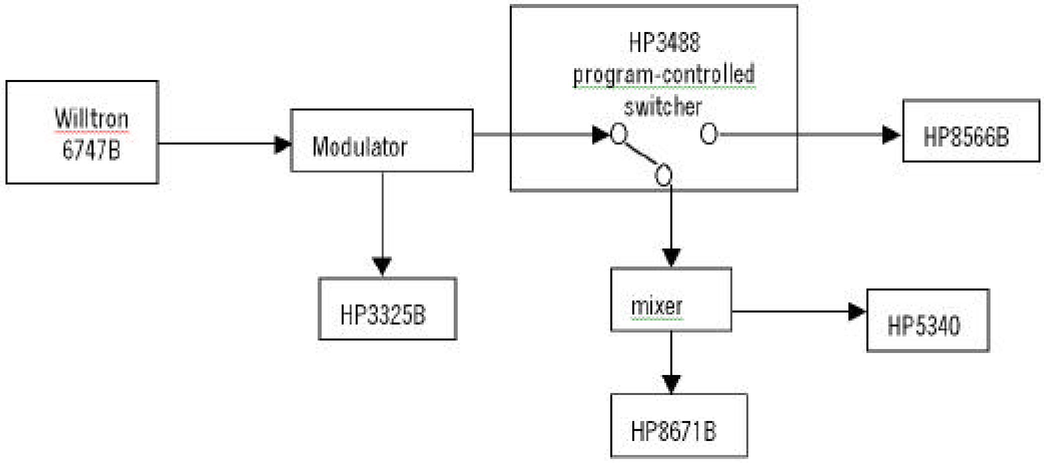


Figure 3. System Connection Diagram

The measurement software has four parts: system configuration checking and assigning language interface, Bessel function zero value method, amplitude comparison method, and counter method. Each part is composed by the followings: instrument control program, HP-IB interface management program, measuring data analysis and processing program, command judgement and program composition choice.

The mission which software complete is inspecting the statement of the instruments to be requested or not. If the statement is “right”, it will transmit the measuring data. Depend on the statement and data, it can generate corresponding measure algorithm, accomplish the great frequency deviation measurement by not numerical algorithms computation methods of table checking, extremum searching, etc., then it will print out the results. If the statement is “false”, the software will previously compile the related theories and project experience of high level measuring technical personnel into data and conditions and store them in the program. Under the data and conditions, software will judge the statement of the instruments, generate an adjusted scheme to change the instrument’s statement until it becomes “right”. Then data can be transmit and operated, and the result is printed out.

The accomplishment of final measuring needs no intervention of personnel. The software imitates not only the action but also the thinking of measuring personnel. So the difficulty in software programming is that computer should find the carrier frequency zero instead of personnel, automatically generate a Bessel function, and look for correspondent modulation exponent under certain amplitude ratio value. Others like arithmetic value computation, command control and print output become just easy with the development of automatic measuring level and data structure technologies. The whole software involves the three measuring methods and data operation process is divided into subprograms in function library which can be transferred when ever necessary. Completely modularized, it achieves a typical Expert System.

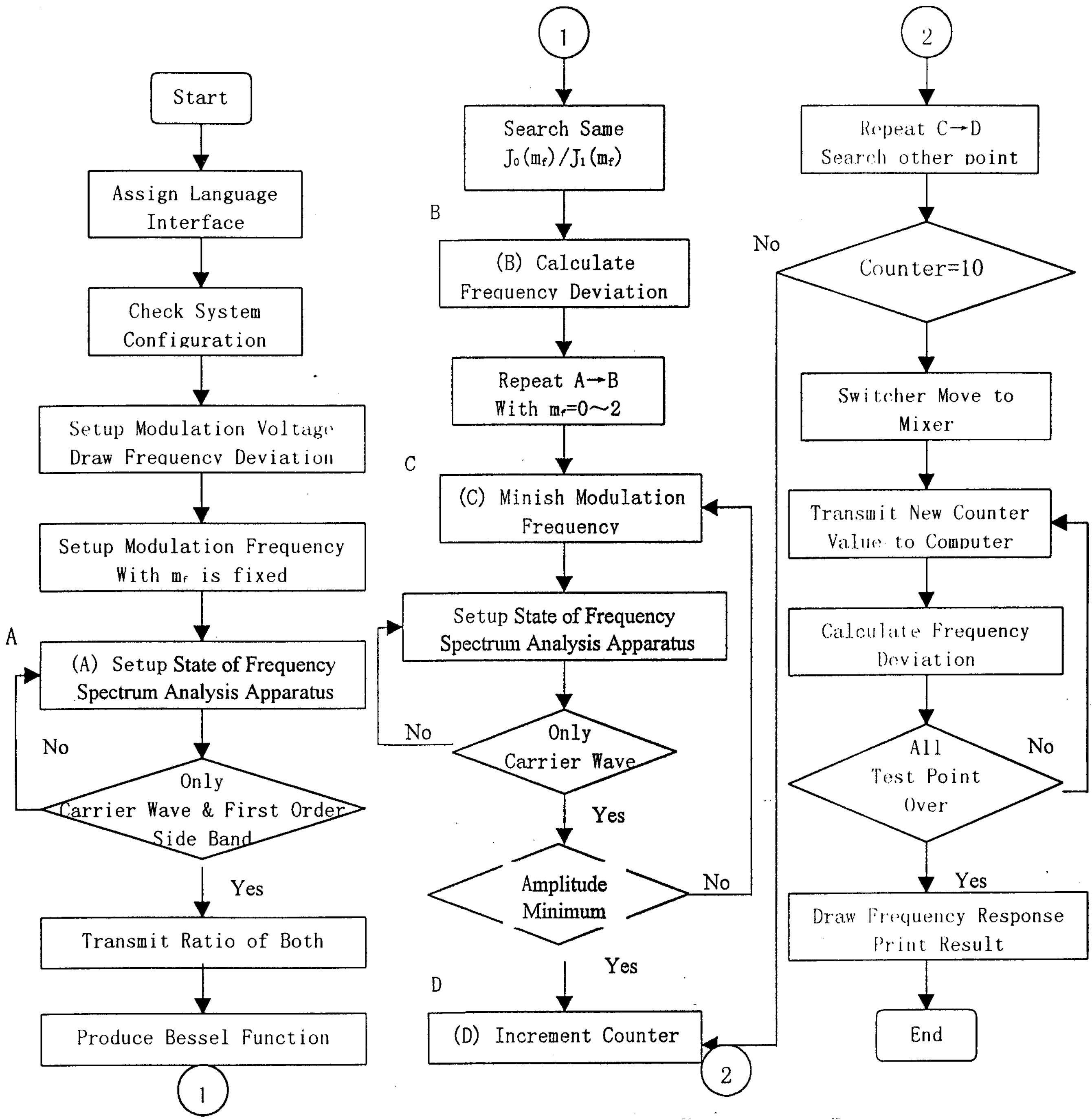


Figure 4. Software Flow Chart of Automatic Measuring

In practical usage, the only thing to do by personnel is to input the modulated voltage into computer, other measuring process is all completed by computer. First, a rough frequency deviation is measured out through counter method. Then, accurate frequency deviation and response can be given by other methods.

APPRASING METHOD FOR THE SYSTEM

Frequency deviation is a derived parameter, so it has no benchmarks. The measurement of it can not be appraised by benchmarks or standards levels as time and frequency can be done. Standard transfer can not do the appraisal of its precision. So the only way to examine the system's precision is measuring contrast.

To test the measuring precision of the system, we made a measuring contrast to the standard frequency synchronizer HP8662A between measuring receiver HP8902A and this system. The result is presented in table 1. It shows that this system has a high measuring precision. Because there's no frequency deviation instrument or standard generator of up 500kHz, there's no way to make the measuring contrast in this range. We can only deduce it from the result in Table 1.

Table 1. Measuring result to HP8662A by the system and HP8902A

Modulate Frequency(kHz)	Δf(kHz)HP8902A	Δf(kHz)measuring system
200	193.5	196.6
150	201.1	198.9
100	201.2	199.7
83.2	200.1	199.6
30	202.1	200.1
1	195.4	194.3
0.5	197.3	199.6
0.1	197.5	201.4
0.05	197.4	201.6
0.01	198.2	201.9

Carrier Wave Frequency: 1.2GHz
Contrasted Absolute Difference Value: 0.5kHz ~ 4.2kHz
Contrasted Relative Difference Value: 0.25% ~ 2.1%

CONCLUDING REMARKS

The great frequency deviation automatic measuring system has been applied in many missions, civil products testing and measurements for frequency deviation and frequency response of some instruments or meters. All the applications showed well effects of the system. It raises the measuring speed, precision and reliability of result. And the system runs stably and reliably. It can not only solve the difficult problem of the great frequency deviation automatic measuring of telemetry transmitter, but also measure the frequency response of modulator in great dynamic range. With computer control, the operation of the whole measurement system can be accomplished by common technical personnel or even the staffs who is not familiar to the instrument usage or not clear to the frequency modulating theories.

The system has been tested domestically and been appraised and censored by an appraisal committee formed up by experts in measuring specialty. It is thought that until now there's no commercial instruments that can be used in measuring the frequency deviation up 500kHz in and out the country. So this system fills a gap and is on top level domestically.

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REFERENCES

Frequency Deviation Meter AN/urm-115A *MIL-F-23640 CANC NOTICE 1 FSC6625

FM Signals Frequency Deviation Measurer ACC No:81B6004D/08108 Priority:780327SU594950

Frequency Deviation from Nominal Value Determine ACC No:81K8555D/08142 Priority:790129SU719536

A Frequency Deviation Transducer with Fast Response Bureau of Reclamation, Denver, Colo. Engineering and Research Center. PB-202 565

High Sensitivity Millimeter – Wave Measurement Apparatus. Department of the Air Force, Washington, Dc. AD-D00969714