Arbeitsberichte der Schweizerischen Meteorologischen Zentralanstalt
Rapports de travail de l'Institut Suisse de Météorologie
Rapporti di lavoro dell'Istituto Svizzero di Meteorologia
Working Reports of the Swiss Meteorological Institute

Zürich

No. 17

Some considerations about digital integrators

by

Dr. Jürg Joss

Air Force Cambridge Research Laboratories
Bedford, Mass.

and

Osservatorio-Ticinese, Locarno-Monti

Applied Meteorology 621.38:681.3:551.501.81

March 1971

Summary:

Video integrators are important parts of weather radars for quantitative measurements. The author emphasizes the advantages of integrators using digital technology over those using analog technology. Two practical models of digital integrators are compared and the technical specifications of a future integrator are presented.

Zusammenfassung:

Videointegratoren sind wichtige Bestandteile von quantitativ messenden Wetterradaranlagen. Die Vorteile von Integratoren in Digitaltechnik gegenüber solchen in Analogtechnik werden hervorgehoben. Zwei praktische Ausführungen solcher Geräte in Digitaltechnik werden verglichen. Es folgt eine Zusammenstellung der Forderungen, die an ein zukünftiges Gerät solcher Art zu stellen sind.

Résumé:

Les intégrateurs de video sont pour des mesures quantitatives, des composants importants d'un système de radar météorologique. On souligne les avantages des intégrateurs en technologie digitale par rapport à ceux de la technologie analogique. On compare deux appareils différents qui sont en service pratique en technologie digitale. On donne enfin une liste des spécifications désirables pour un intégrateur future.

Introduction

The main advantage of using a digital integrator compared with an analog integrator lies in the fact, that the only part which needs calibration is the input analog to digital converter. This part is available off-the-shelf and for the accuracy necessary in this application needs no recalibration after the initial one in the factory. A properly designed digital integrator,therefore,needs no calibration during its use. In addition to that, the reliability is higher, digital circuits are less sensitive to temperature changes and high humidity,and if something has to be replaced this can be done with the equivalent part without recalibration. The price for a digital integrator having 1000 range gates at present is about equal to that for an analog integrator with 200 gates and will be lower in a few years for better performance.

I had the opportunity to familiarize myself with both the integrators developed at MIT and at Raytheon. After summarizing the characteristics of both instruments their best features were put together to form the characteristics of the future integrator. With the present state-of-the-art, the resulting specification characteristics are easy to be met.

1. MIT Integrator

MIT has had their integrator working since 1966 and in routine operation since 1967. The integrator has 714 gates spaced 2 µs apart. Up to 256 independent samples in time and/or space may be averaged. The results are normalized for the number of samples being averaged and normalized for range. Out of 15 levels three are displayed at once on the PPI. It is felt that what would be gained by putting more than three contours at the same time on the PPI is not worth the added ambiguity. Now a more elaborate weather radar processor is being developed which will analyse the data to a much wider extent. It is felt that rather than going back on the PPI, information should be stored in a more compact form such as accumulated rain patterns etc. For published results see e.g. Oklahoma Conference p.28, Tucson Conference p. 330, p.375 and p. 439 etc.

2. Raytheon Integrator

Their first digital integrator worked in 1967 using a core memory. Since then two successive versions have been developed both using MOS-shift registers for storing the information. The second one has 1200 range bins having a width of .5, 1 or 2 µs. Up to 8192 sweeps may be integrated (no range integration). The range normalized output is available for display on a PPI. Up to seven contours out of 31 can simultaneously be chosen for display represented by black, white or grey areas. Two digital words containing range, (11 bits), and intensity, (7 bits), are available at each range for computer processing. Publications, see e.g. Tucson Conference p.387 etc.

3. A Sketch of the Future Integrator

The proposed integrator would be a versatile instrument fulfilling the requirements of the WSR 57, the weather radar widely operated at present by the U.S. Weather Bureau, as well as the ones for a better future replacement for it. It would answer to the needs of a horizontally looking radar for larger distances as well as the ones of a vertical pointing radar. The digital components are cheap at present and getting cheaper every month, so that I feel that we should head for the ideal future digital integrator rather than for a cheap version, where range and amplitude resolution is sacrificed for a 20 % smaller price. The small complications added are well worth the improvement obtained in smoother contours and increased versatility. In the following, some features will be discussed briefly.

a. The analog-digital converter should have five and preferably six bits in order to reduce quantizing noise. The conversion should be made immediately after Log IF amplifier in order to avoid calibration problems. Any integration before the conversion should be avoided because this would reduce the standard deviation of the natural fluctuations. This would mean, that the errors of the A-D quantizing would not be smeared out as well and therefore finer quantizing steps would be necessary at the input A-D converter. (MIT, 4 bit; Raytheon, 5 bit)

b. The range resolution should be 2 μs, preferably 1 μs, ideal .5 μs. (MIT, 2 μs; Raytheon, 0.5, 1, 2 μs)

c. The integrator should allow integration in space as well as time (MIT, range and time; Raytheon, time only).

d. The weighing function should be constant for the time of integration and zero afterwards (MIT) rather than decaying exponentially with time (Raytheon) because of the following reason: If we accept a given amount of smoothness and smearing of the contours, the antenna may be rotated faster when a rectangular weighing function is applied.

e. The range normalization steps should not be coarser than .5 db. A read-only memory will probably provide the most convenient solution to this requirement. (MIT, 1 db analog generated; Raytheon, 1.5 db digital)

f. Out of 31 levels it should be possible to display six simultaneously on a PPI with a black-grey-white coding. Displaying six contours together may be desirable for certain applications. For most operational circumstances, however, I agree with MIT that three contours are sufficient and desirable for easy distinguishing. (MIT, 3 out of 15; Raytheon, up to 6 out of 31)

g. It should be possible to place the 32 levels covering the operating range indicated in Fig. 1. Note that the input A-D has to cope with a log signal corresponding to a linear dynamic range of 90 db, including 40 db of range correction. Log receivers for this application can be bought off-the-shelf. If one is mainly concerned with strong rain, the operating range may be easily shifted to higher intensities, just by inserting a fixed attenuator.

h. Contour suppression has to be provided in order to eliminate signals produced by the range normalization alone, that is at ranges exceeding the intersection of the range correction and the contour.

i. A digital word for each range bin should be provided for further processing of the data with a computer. (MIT and Raytheon, o.k.)

j. Flexibility with the PRF is a big advantage and easy to get when shift-registers are used to store the data. This allows the integrator to be triggered by the radar. On the other hand, for the delay-line type integrator the PRF of the radar has to be matched to the integrator (MIT uses a delay-line at present for a PRF of 350; Raytheon, shift registers which allow the integrator to be operated with a radar having a PRF in the range of 200 to 1600).

Summing up, it is quite obvious that much progress has been made since Kodaira's excellent work with analog integrators in 1955.

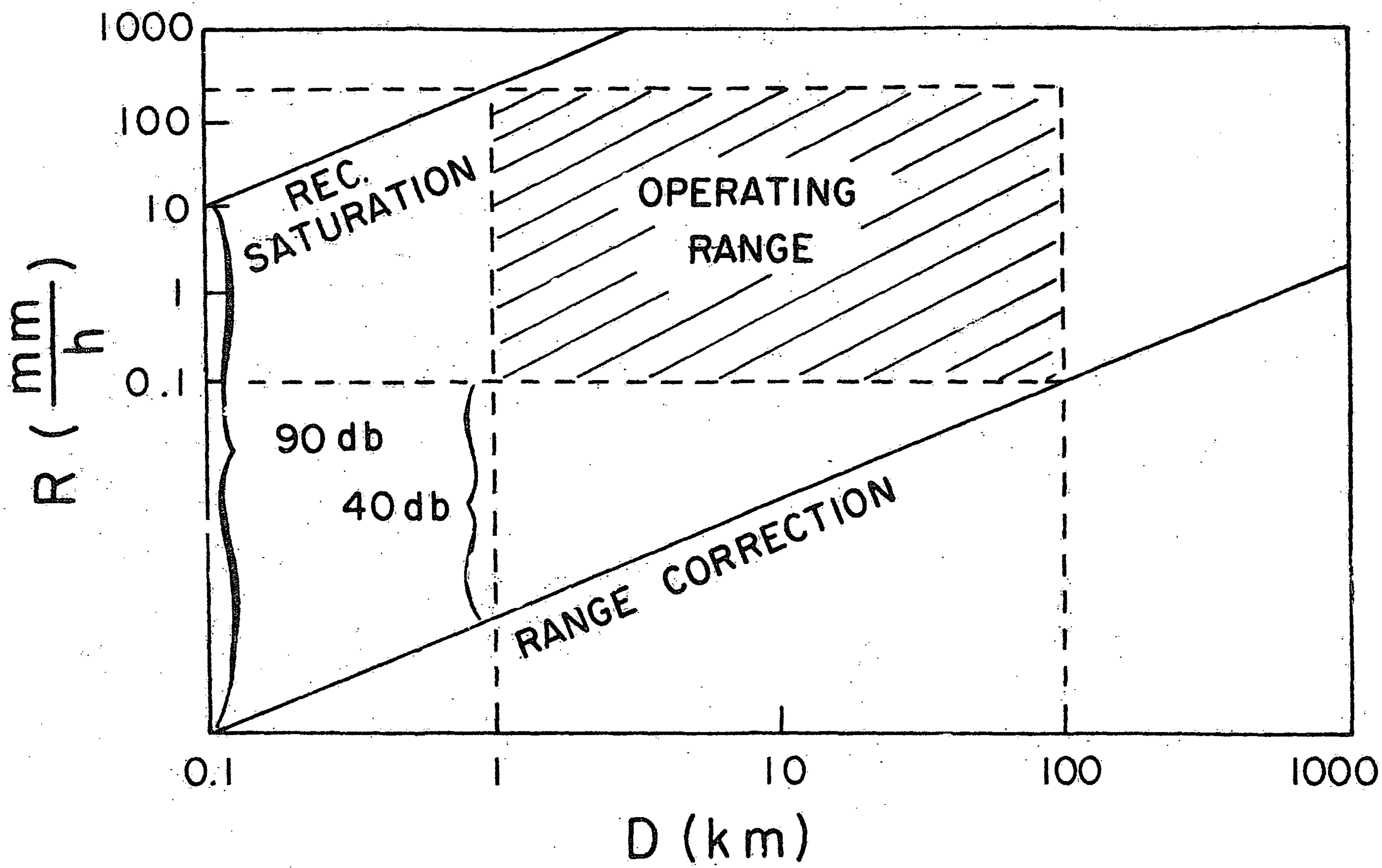

Fig. 1 Assuming a dynamic range of 90 db between the saturation of the log receiver and the thermal noise (of the mixer and the log receiver together) the ability to measure a rain intensity by R at a distance D is plotted. To normalize the signals versus range the range correction has to be added to a signal according to the distance where it is coming from.